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Volume 3: Wilderness as a Place for Scientific Inquiry

Missoula, Montana
May 23–27, 1999

Abstract

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Thirty-six papers related to the theme of wilderness as a place to conduct science are included. Five overview papers synthesize knowledge and research about basic work in the biophysical and social sciences that has been conducted in wilderness. Other papers present the results of focused basic research in wilderness, with one set of papers devoted to the conduct and management of science in wilderness.

Keywords: landscape ecology, paleoecology, populations, therapeutic experiences, visitor experiences, wilderness benefits, wildlife

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Compilers

Stephen F. McCool
David N. Cole
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Preface

The Wilderness Science in a Time of Change Conference was held in Missoula, Montana, May 23 through 27, 1999. The conference was conceived to be both a followup and an expansion of the first National Wilderness Research Conference, held in Fort Collins, Colorado, in 1985. That conference brought together most of the scientists in the world who are working on issues related to the management of wilderness and resulted in literature reviews and compilations of research that remain critical references today (Lucas 1986, 1987). Our intent was to bring scientists together again, along with wilderness managers, to produce an updated compendium of the current state-of-knowledge and current research. In addition, we sought to increase the array of scientific disciplines represented at the conference and to expand the range of topics beyond the challenges of managing wilderness. Finally, we hoped to use plenary talks to highlight controversy, divergent viewpoints, and management dilemmas—to challenge participants' belief systems—in the hopes that this would stimulate interaction and personal growth.

Well over 400 people participated in the conference. Conference attendees included a roughly equal mix of people from federal land managing agencies and from academia. There were also several representatives from state, local, and tribal governments. There were more than 30 attendees from 16 different nongovernmental organizations, as well as a number of private individuals, consultants, and members of the press. About 20 participants were from Canada, with about 20 more participants from other countries. We succeeded in attracting people from diverse disciplines, united in their interest in wilderness. As usually is the case, a large proportion of the researchers who attended specialize in the social science aspects of outdoor recreation. However, attendees also included other types of social scientists, philosophers, paleontologists, and life scientists interested in all scales of analysis from cells to the globe.

The conference consisted of plenary talks to be presented before the entire conference, as well as more narrowly focused presentations organized around three conference themes and presented in concurrent sessions. The conference's plenary talks were organized into four sessions: (1) global trends and their influence on wilderness, (2) contemporary criticisms and celebrations of the idea of wilderness, (3) the capacity of science to meet the challenges that wilderness faces and to realize the opportunities that wilderness presents, and (4) concluding talks related to conference themes.

The bulk of the conference was organized around three themes. The first theme was "Science for Understanding Wilderness in the Context of Larger Systems." The emphasis of this theme was better understanding of the linkages between wilderness and the social and ecological systems (regional, national, and international) in which wilderness is situated. The emphasis of the second theme, "Wilderness for Science: A Place for Inquiry," was better understanding of what we have learned from studies that have utilized wilderness as a laboratory. The third and most traditional theme was "Science for Wilderness: Improving Management." The emphasis of this theme was better understanding of wilderness visitors, threats to wilderness values, and means of planning for and managing wilderness.

We organized three types of sessions under each of these three themes. We invited 18 speakers to present overview papers on specific topical areas under each theme. Many of these speakers developed comprehensive state-of-knowledge reviews of the literature for their assigned topic, while others developed more selective discussions of issues and research they judged to be particularly significant. In addition, conference participants were given the opportunity to contribute either a traditional research paper or to organize a dialogue session. Most of the research papers (131 papers) were presented orally, but 23 additional papers were presented in a poster session. The 14 dialogue sessions were intended to promote group discussion and learning.

The proceedings of the conference is organized into five separate volumes. The first volume is devoted to the papers presented during the plenary sessions. Subsequent volumes are devoted to each of the three conference themes, with two volumes devoted to wilderness management, the theme with the most papers. Within each theme, papers are organized into overview papers, research papers, and papers from the dialogue sessions. The format of dialogue session papers varies with the different approaches taken to capture the significant outcomes of the sessions. Research papers include papers presented orally and on posters. Within each theme, research papers are organized into broad topical areas. Although the initial draft of each proceedings paper was reviewed and edited, final submissions were published as submitted. Therefore, the final content of these papers remains the responsibility of the authors.

We thank the many individuals and institutions on the lists of committee members and sponsors that

follow. They all contributed to the success of the conference.

Planning Committee: Joan Brehm, Perry Brown, David Cole, Wayne Freimund, Stephen McCool, Connie Myers, and David Parsons.

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References

Lucas, Robert C., comp. 1986. Proceedings, national wilderness research conference: current research; 1985 July 23-26; Fort Collins, CO. Gen. Tech. Rep. INT-212. Ogden, UT: Intermountain Research Station. 553 p.

Lucas, Robert C., comp. 1987. Proceedings, national wilderness research conference: issues, state-of-knowledge, future directions; 1985 July 23-26; Fort Collins, CO. Gen. Tech. Rep. INT-220. Ogden, UT: Intermountain Research Station. 369 p.

—The Compilers

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Wilderness as a Place for Scientific Inquiry

Stephen F. McCool
David N. Cole

One of the most fundamental rationales advanced for protection of areas as wilderness is their immense potential value as baselines and places for comparing the effects of ever-advancing human development and impact (Brower 1960). In contrast to more developed areas, wilderness is characterized by lack of human development and related disturbances. By protecting large landscapes from development and impact, scientists may be able to uncover, and come to understand, natural processes that would be hidden in more developed settings. By preserving relatively undeveloped areas, changes in biophysical and ecological conditions wrought by civilization can be better measured, assessed, and evaluated. Through management regimes that allow natural processes to occur in a relatively unfettered manner, we will better comprehend their extent and variability. Through this understanding, the number, type, and frequency of ecological surprises may be reduced.

Wilderness is fundamental to understanding the natural capital with which humans have been blessed. Wilderness that serves as a baseline for monitoring allows us to detect processes and conditions that may be adverse to human life, or the plants and animals upon which it depends. A good example is the current threat to whitebark pine ecosystems, much of which occurs in designated wilderness. Fire suppression and the introduction of the exotic disease whitepine blister rust are largely to blame for significant reductions in the population and spatial extent of whitebark pine. Wilderness allows scientists to isolate the effects of these two exogenous influences and separate them from other human-induced processes and effects. By so doing, we come to a higher level of understanding of how natural processes operate, and the surprises that occur when those processes themselves are disturbed or experience interventions by people.

Of course, there are no absolutely pristine places on earth—but the over 100 million acres of wilderness designated in the United States does provide a substantial benchmark, one that could be improved primarily by achieving greater representativeness in landscape types and through more expeditious scientific use of those areas.

Wilderness also provides distinctive and unique benefits to people, other than the clean air and pure water upon which many people depend. Wilderness is a place to escape the hazards, stresses, and challenges of an increasingly urbanized world. It may be one of the few places left where one is not continually disoriented by the ring of cellular phones, the stress of urban congestion, and the anxiety created by growing violence. Understanding what social-psychological values wilderness provides is as important as assessing their benefits for investigating natural processes. The therapeutic, inspirational, and personal enhancement values of wilderness, while only poorly understood currently, may ultimately be responsible for a greater awareness and sensitivity of human impact on the global environment, for without these places, the room to experience, to contemplate, and to understand is lost.

Thus, wilderness is established, in part, to encourage science, and the above sampling of how science can benefit from wilderness is suggestive of the types of opportunities for research and scholarly activity that wilderness provides. However, the science that occurs must also be consistent with the cornerstones of wilderness ideals—naturalness, untrammelled character, solitude, and unconfined recreation. Thus, management of science itself becomes a major question, for in seeking understanding in these places, we cannot violate the values for which they were established. This makes the conduct of science in wilderness difficult. It makes a consistent science policy for wilderness mandatory. It suggests the need for an ethical foundation. And, it suggests that conflicts with other legislation (such as the Threatened and Endangered Species Act) are inevitable.

The conference devoted attention to discussion of many of these values and issues, and in this volume, we present papers submitted for these topics. The volume is divided into five major sections. The first section consists of overviews and assessments of knowledge generated in wilderness concerning specific science questions. In this section, Alan Ewert and Leo McAvoy identify the knowledge scientists have developed when wilderness is used in a structured, therapeutic manner for those in times of crisis and difficulty. Their assessment suggests that there is great opportunity in this arena that is provided by wilderness. Joe Roggenbuck and Bev Driver similarly review the research dealing with the specific benefits that wilderness provides to people that experience it. Jerry Wright and Lisa Garrett summarize the extensive amount of research on wildlife that has occurred in wilderness, indicating that it has become an important source of knowledge for understanding how natural processes affect one type of biota. Norm Christensen reviews what science has learned about ecosystems from wilderness, particularly about such processes as disturbance and change, landscape dynamics, and community. The role of wilderness in "disentangling" change as a result of natural and anthropogenic influences is reviewed in Lisa Graumlich's paper.

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Section two includes a number of papers that examine wilderness from an ecosystem perspective, including those that use wilderness as a baseline to compare with other areas. Three papers dealing with research in wilderness about aspects of the past are included in section three. The use of wilderness as a laboratory to study interactions of people and their environment is the subject of papers included in section four. Management of science in wilderness is a particularly perplexing topic as indicated earlier, and several papers submitted to the conference are included here as section five.

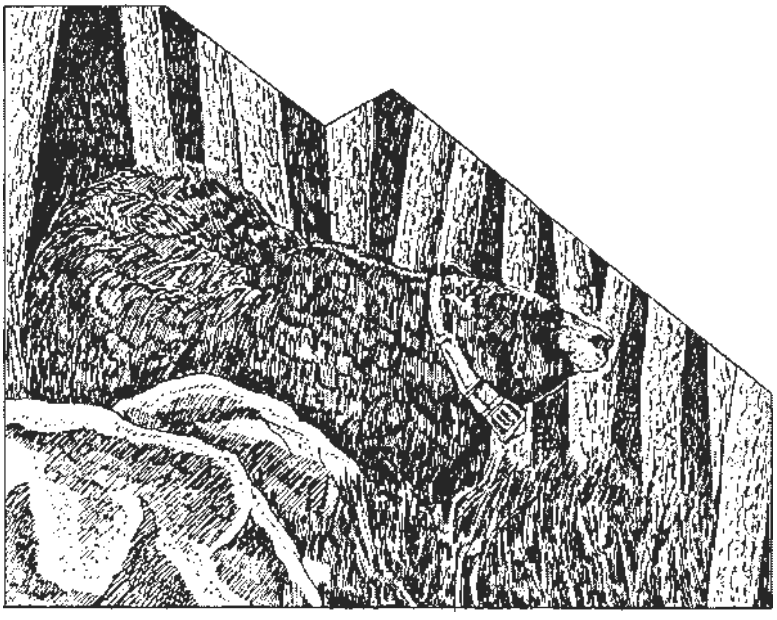
The final section of this volume involves dialogue sessions dealing primarily with the topics of management of science and monitoring of ecological trends—issues for which there are a variety of opinions and options.

The coverage here does not include at least two of the major issues often discussed as principal values of wilderness: its utility as a gene pool and its value as, in Dave Foreman's words, a "cauldron of evolution." Mapping and assessing those values are critical to developing the wide-ranging purposes of wilderness. Perhaps a future conference will more specifically address this fundamental value.

References

Brower, D. R. 1960. Meaning of wilderness for science—Proceedings Sixth Biennial Wilderness Conference. Sierra Club, San Francisco, CA. 129 p.

1. Overviews



The Evolving Role of Science in Wilderness to Our Understanding of Ecosystems and Landscapes

Norman L. Christensen, Jr.

Abstract—Research in wilderness areas (areas with minimal human activity and of large spatial extent) formed the foundation for ecological models and theories that continue to shape our understanding how ecosystems change through time, how ecological communities are structured and how ecosystems function. By the middle of this century, large expanses of wilderness had become less common and comparative studies between undisturbed and human-dominated landscapes were more prevalent. Such studies formed the basis an evolving understanding of human impacts on ecosystem productivity and biogeochemical cycling. Research in the last third of this century has repeatedly taught us that even the most remote wilderness areas are not free of human influence. Nevertheless, extensive wilderness has been and will continue to be critical to our understanding our impacts on nonwilderness landscapes.

No one would quibble with the assertion that research in wilderness has been important to our understanding of the functioning of ecosystems and landscapes: the majority of papers published in ecological journals over the past century were either done in or make heavy reference to ecosystems in which human impacts are minimal. As so many papers in this volume have demonstrated, our vision of wilderness over the past century (corresponding roughly to the period during which the field of ecology as a formal discipline was born and has matured) has changed considerably as a consequence of research in wilderness. Our visions of wilderness have just as surely shaped the core values and character of ecosystem and landscape science.

I have chosen to focus on the evolution of ecological sciences over the past century—1899 to 1999. Much ecological research certainly predates this time period, although it does coincide roughly with the recognition of ecology as a formal academic discipline, as evidenced by establishment of faculty chairs and peer-reviewed journals devoted to this topic. I shall dwell in particular on three areas of inquiry—1) disturbance and change, 2) the nature of the community and 3) the "physics" of the ecosystem—that were born and matured during this time period. I conclude with reflections on the evolution of ecosystem and landscape science in relation to our understanding of our relationship to wilderness.

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Disturbance and Change

Henry Chandler Cowles' (1899, 1901) studies of succession on sand dunes newly exposed by the retreat of the Lake Michigan shoreline initiated a search for a unifying theory of ecosystem change that continues to this day. Cowles' primary interest was in understanding the relationship between the process of vegetation change and landform evolution. He did not advocate a unifying theory for successional change in this work, but his assertions on several important points were central to the evolution of such a theory. These assertions included directional change converging on a stable climax community and "biotic reaction," that is, organismal influences on the environment as a driver of change.

A Unifying Theory of Change

It was Frederick Clements (1904, 1916, 1932), drawing on observations from both natural and human-disturbed situations, who must be credited or blamed for asserting a comprehensive theory of succession. Building on Cowles' notions of convergence and biotic reaction, Clements saw succession as driven by a combination of biotic reaction and competition among dominant species proceeding in relatively discrete stages along a sere that culminates in the most stable assemblage of organisms imaginable, the climax community. He argued that climate was the ultimate determinate of the character of that climax, all other environmental influences being ameliorated by biotic reaction. Competition sharpened the boundaries or ecotones between such communities in space and among seral stages in time. Although he did not use this exact phrase, Clements envisioned communities as highly coevolved entities with a similarity to organisms that is far more than metaphorical.

Clements had much to say about the character of the world's wilderness prior to significant human influences.

> Under primitive conditions, the great climaxes of the globe must have remained essentially intact, since fires from natural causes must have been both relatively infrequent and localized. Succession was far less general and was represented chiefly by priseres, especially in water and dune sand; subseres were few in number and small in extent. They became universal features only as man extended his dominion over nature through disturbance and destruction and they are permanent today in the degree to which these forces are continuous or recurrent. From the very nature of climax and succession, development is immediately resumed when the disturbing cause ceases, and in this fact lies the basic principle of all restoration and rehabilitation. Left undisturbed, every bare denuded or seral area begins its slow but

> inevitable movement to the climax wherever the latter has not been destroyed over too large a territory to permit mobilization of the successive populations (Clements 1935).

This quote is from a paper entitled "Experimental Ecology in the Public Service" and certainly reflects the prevailing views at that time about the proper focus of wilderness conservation (climax communities) and the need to exclude disturbances, especially fire.

A Theory Challenged

Today, we often depict Clementsian successional theory as the prevailing paradigm among ecologists for the first half of this century. Perhaps this is because of its simplicity and apparent explanatory power, its impact on policies and protocols for managing land resources and public agencies or its incorporation into so many ecology textbooks. But the fact that this theory has served as the starting point or straw man for so much research on ecosystem change over the past four decades has certainly reinforced that view. It is, however, important to note that views contrary to Clements' doctrinaire approach to succession were commonplace early in this century, and those views were most often shaped by observations and data from wilderness areas. Several important themes from that work have influenced research up to the present. I refer to these as 1) the lexicon of climaxes, 2) the ugly fact of "retrogression" and 3) the inevitability of change.

The Lexicon of Climaxes—It was early observed that, even in seemingly undisturbed areas, rather stable communities existed that did not match up with the expectations for climax assemblages within particular climatic regimes. It appeared to many that unique hydrologic conditions (Cain and Penfound 1938; Harper 1914), geology (Billings 1950; Platt 1951), soils (Wells and Shunk 1932) or salinity (Wells 1939) were often sufficient to prevent biotic reactions from pushing change to one climatically-determined endpoint. One approach to this dilemma was a proliferation of terms such as preclimax, disclimax, edaphoclimax, aquatic climax and topoclimax to describe this variation (for example Hansen 1921). Indeed, Whittaker (1953) counted no fewer than 36 types of climaxes named in the literature. Another approach was to abandon the notion of "climatic monoclimax" altogether in favor "polyclimax" or succession to stable endpoints determined by site-specific environmental factors such as soils, hydrology and topography (Cain 1939; Oosting 1948; Tansley 1935). This idea preserved many of the elements of Clements' theory, but discounted the primacy of climate.

The Ugly Fact of Retrogression—One of the most appealing features of Clements' world view is that succession leads inexorably to the best possible community configuration within the constraints set by the environment. This feature was highlighted in Odum's (1969) trends to be expected during succession. Whether succession could lead to less fit community configurations was a matter of considerable debate early in this century. Clements (1916) opined that such change was not possible, whereas others cited evidence from a variety of wild areas that it was in fact common (Cowles 1901, 1919; Cooper 1916, 1926). An oft-cited example of such retrogression is the succession of white spruce forests to black spruce "muskegs" owing to hydrologic and microclimatic changes wrought by the maturation of the white spruce canopy and associated ground-layer vegetation (Cooper 1916).

The Inevitability of Change—Climatic constancy over millennial time spans would seem to be a prerequisite for climatic monoclimax; however, the variability of climate over time spans relevant to successional change was appreciated early on. It is significant that Cowles (1911) recognized the importance of this fact in his characterization of succession as a "variable converging on a variable." The idea that communities become increasingly resistant to change—intrinsically more stable—through succession was, nevertheless, widely held. Indeed, if a climax community is the most stable configuration of species possible in a particular environment, how could it be otherwise (Peters 1976)?

Very early in this century, ecologists were becoming aware that disturbance, particularly fire, was important on many landscapes. In papers that contain many of the elements of modern-day landscape ecology, Harper (1911, 1914) emphasized the importance of repeated wildfires on the structure and spatial distribution of vegetation in north Florida and in the Everglades. Garren (1943), Harper (1940) and Wells (1942) recognized the importance of fire across the entire southeastern coastal plain. Cooper (1922) cited the prevalence of fire in the Mediterranean ecosystems in California, and he described many of the adaptations of species in those ecosystems to fire. However, it was Sampson (1944) who first understood that accumulation of woody debris and biomass during succession in chaparral shrublands actually made them more susceptible to fire.

It was work by Biswell (1967) and Kilgore (1973) in the giant sequoia forests of the central Sierra Nevada which showed that the connection between successional change and the likelihood of disturbance was complex indeed. They demonstrated that, in the absence of frequent (every 8-15 years) light surface fires in giant sequoia groves, shade-tolerant species of fir and incense cedar invaded the understory. This, coupled with the accumulation of woody debris, made crown-killing fires more likely. Furthermore, in the absence of fire, seed germination and seedling establishment of the giant sequoias were very limited.

Cyclic Change and Pulse Stability

That ecosystems displayed cybernetic behavior—that is, behavior constrained by internal feedbacks—was a matter of great interest and debate during the decades of the 1950s and 1960s (for example, Margalef 1957, 1968; Odum and others 1960). Odum (1969) saw directional change toward a stable climax as an inexorable consequence of such behavior. In his view, as succession proceeds, regulation of change becomes increasingly autogenic (that is, cybernetic). However, Loucks (1970) and Jordan (1972) pointed out that autogenic changes could also lead to cyclic behavior—pulse stability (Loucks 1970) or bounded instability (Jordan 1972). In this model, succession produces changes that make a community more susceptible to disturbance.

The disturbance, in turn, generates renewed process of succession.

The idea of cyclic succession certainly predates the coining of terms like pulse stability. Harper (1911). Wells (1942) and Garren (1943) certainly appreciated the importance of repeated fire on the southeastern landscape, although they may not have grasped the fact that fire probabilities were driven in part by autogenic changes within these ecosystems. The connection between fire probability and fuel accumulation was, however, well understood early on (for example, Biswell and others 1952; Cooper 1961; Sampson 1944). Mutch (1970) suggested that natural selection in such ecosystems may well have produced plant characteristics that increased flammability, thus ensuring regularity in fire cycles (see, however, Christensen 1985).

The so-called thaw-lake cycle on the wet tundra of the north slope of the Brooks Range of Alaska represents pulse-stability on a much longer time scale (Bliss 1988; Peterson and Billings 1978). Here, the landscape cycles among various stages of polygonized ground and shallow lakes are driven by autogenic changes in surface energy budget, location of ice wedges and the depth of the permafrost layer.

That change is constant and cyclic is actually very much a part of Watt's (1947) much celebrated model of pattern and process in the plant community (see also Bormann and Likens 1979). In Watt's view, it was primarily the spatial scale of disturbance and recovery patterns that change through time; that is., the processes of change in small-scale disturbances (a windthrow, say) in mature ecosystems in many ways replayed the larger-scale patterns of change that produced the ecosystems in the first place.

That change in wilderness areas is more complex than autogenic trajectories leading to stable climaxes or autogenic stable-limit cycles is obvious from the detailed descriptions in the work by individuals such as William Cooper, Homer Shantz, Roland Harper, B.W. Wells and Stanley Cain that filled the pages of ecological journals during the first four decades of this century. Nevertheless, the notion of autogenic change is implicit in the "balance of nature" concept that was (and to some extent still is) a basic assumption that scientists brought to their studies of wilderness. Furthermore, as I discuss below, both of these notions provided the justification for management policies and protocols that were consistent with our historic view of wilderness and the role of humans in it.

Patch Mosaic Landscape Dynamics

The prevailing paradigm for understanding ecosystem change is captured in the phrase "patch mosaic" landscape dynamics. While wilderness has played a significant role in the development of this concept, it has its roots in studies of near-shore and intertidal marine ecosystems and of islands.

The focus of early discussion surrounding MacArthur and Wilson's (1967) equilibrium theory of island biogeography was on the properties of islands that rendered them more or less species rich, But it was the assertion that the species diversity of place was a consequence of an endless balance between immigration and local extinction that would revolutionize our thinking about the structure of wilderness communities. Rather than a static property of climax ecosystems, diversity is now seen as a dynamic feature, subject to change based on factors that influence immigration and factors that put populations at risk.

Working on the communities of sedentary invertebrates and algae that "foul" virtually any solid surface, Sutherland (1972) suggested the idea of "multiple stable points"—that communities might change continuously in structure, but that certain assemblages of species were more stable than others and thus persisted for longer periods and consistently reappeared from time to time. This idea was given a "spatially explicit" context in the work of Levin and Pain (1974) and Pain and Levin (1981) in which they demonstrated that the "landscape" of the intertidal zone could be viewed as a spatial array of patches undergoing change and that the nature of that change was a consequence of within-patch autogenic process, patch size, and the relationship of the patch to other patches. This latter factor was important as it influenced opportunities for immigration to a patch. Perhaps the most important lessons from this idea are that spatial scale influences change, and it matters where a patch is relative to other patches on a landscape.

Terrestrial ecologists working in a variety of wilderness areas were quick to see the importance of this concept. Sprugel's (1976, 1984) description of the waves of disturbance and regeneration that move through the spruce-fire forest of the northeastern Appalachians captures many of the elements of Levin and Paine's model, particularly the importance of spatial relationships. Work by Romme (1981) and Romme and Knight (1981, 1982) set the stage for the widespread application of patch-mosaic thinking in the Greater Yellowstone Ecosystem following the 1988 fires (Romme and Despain 1989). Myers' (1985) work on the distribution of sand pine scrub, long-leaf pine-wiregrass and live oak ecosystems on the central Florida sand ridge provides a very compelling example of patch mosaic landscape dynamics.

Landscapes can be modeled in terms of a demography of patches, characterized by a matrix of transition probabilities describing the likelihood of a patch in a particular state changing into some other state over a particular period of time. Such probabilities are known to be affected by the autogenic processes driving change within a patch (thus capturing concepts from earlier theories of change), the size and configuration of a patch, the character of surrounding patches, and extrinsic factors that might influence disturbance. This is made more complex by the certain knowledge that such a matrix cannot be "stationary," but that these probabilities are shifting through time with changes in climate and the overall structure of the landscape mosaic (Usher 1979; White and Pickett 1985). Precisely defining such a transition matrix for any landscape would be daunting, but understanding the factors that might determine such probabilities continues to be an important focus for research in wilderness areas.

The Community

The field of systematics is blessed with the fact that organisms, notwithstanding some messiness caused by hybridization, asexual reproduction, etc., can be classified in a natural hierarchical taxonomic system. We say

it is natural because it is a consequence of the process of evolution and its basic units, species, are created (at least in higher organisms) as a consequence of reproductive isolation. Although genetic variation within species is typically rampant, there is general acceptance of the notion of genetic discontinuity among species.

It seemed reasonable to those first studying wilderness landscapes that assemblages of organisms might be classified in some sort of similar "natural" taxonomy, based on an understanding of the underlying factors or processes that produced those assemblages. That certain assemblages do repeat themselves seemed apparent to most early students of wilderness. C.H. Merriam's (1898) "life zones" may represent the first attempt at such a natural classification. Merriam noted distinct transitions from major physiognomic types (desert, grassland, shrubland, forest, etc.) as one proceeded from low elevation to higher elevation in the mountains of the desert Southwest, which he described and named as distinct zones (Sonorran, alpine, etc.). Furthermore, he called attention to the similarity between elevation and latitudinal transitions in such zones. These life zones were recognized primarily by physiognomy and by their dominant species. Merriam assumed that climatic variation along elevational and latitudinal gradients was the factor underlying these zones, but he did not consider why such zones would be so distinct, given the gradual variation in climate.

Clements' ideas on vegetation change and the nature of the community provided the basis for a much more sophisticated hierarchical taxonomy of communities. Clements (1932) shared Merriam's conviction that climate was the overriding environmental factor affecting the distribution of plant communities, and he went on to provide a basis for why such communities would have abrupt boundaries in space and time. Clements argued that one could speak of communities in the "abstract" as idealized notions that had reality as a consequence of the biotic reactions of and competition among dominant organisms. In the same way that each of us can be grouped in the unit *Homo sapiens*, the "concrete" community was that spatially bounded entity that one encountered on the ground, and the abstract community was the taxonomic unit to which it belonged. The biotic reactions of dominant species ameliorated the environment in a way that created extensive uniform environments in their understories in the face of more gradual and continual change in climate. The boundaries or ecotones between communities were sharpened by competition among the dominant species.

The notion of the abstract community was central to Clements' organismal concept. Clements was convinced that the natural processes of autogenic change, biotic reaction, dominance and competition inevitably produced highly coevolved communities, and he posited an elaborate taxonomic hierarchy of formations, associations, sociations, communities, etc. as a natural consequence of those processes.

Although it would appear that few ecologists even in Clements' time accepted his climatic monoclimax theory (Cain 1939; Cooper 1926), the question of whether communities, abstract or concrete, really existed persisted—indeed dominated much debate among plant ecologists—well into the latter half of this century. One of the strongest latter-day proponents of the fundamental existence of abstract communities (he referred to them as "typal") was Rexford Daubenmire (1966), working in wilderness in eastern Washington state. Like Clements, Daubenmire argued that autogenic processes (biotic reaction and competition) within communities produced extensive relatively homogeneous communities with abrupt boundaries. (I am purposefully not treating the very detailed community classification system of Braun-Blanquet (1932) still in wide use in Europe. I use the lame excuse that it was developed largely on human-impacted landscapes. Because this system is based on the fidelity of individual plants to unique environments, one could argue that it is quite "Gleasonian").

In his 1926 exposition of his "individualistic" view of the plant community H.A. Gleason describes a variety of landscapes in wilderness as diverse as Cascadia, the Andes, the desert and the complete run of the Missouri and Mississippi Rivers in which discrete communities appear to be absent.

> In conclusion, it may be said that every species of plant is a law unto itself, the distribution of which in space depends upon its individual peculiarities of migration and environmental requirements. Its disseminules migrate everywhere, and grow wherever they find favorable conditions. The species disappears from areas where the environment is no longer endurable. It grows in company of any other species of similar environmental requirements, irrespective of their normal associational affiliations. The behavior of the plant offers in itself no reason at all for the segregation of definite communities. Plant associations, the most conspicuous illustration of the space relation of plants, depend solely on the coincidence of environmental selection and migration over an area of recognizable extent and usually for a time of considerable duration. A rigid definition of the scope or extent of the association is impossible, and a logical classification of associations into larger groups… has not yet been achieved.

Indeed! In his later (1939) treatise on this individualistic concept, Gleason did allow as how biotic reaction and competition might be important as part of the environment at a given location, but he argued that these processes should themselves vary in gradient fashion. This concluding paragraph from Gleason's 1926 paper on the community seems to lead almost directly to such modern concepts as the equilibrium theory of island biogeography and patch mosaic landscape dynamics.

Unquestionably, the assumptions that ecologists carried with them into the wilderness influenced the way in which they interpreted it. Indeed, those assumptions very much drove the methodologies they brought to bare on this debate. In Daubenmire's (1966) words, "it appears to me that if one selects any of several appropriate methods, one can demonstrate a continuum anywhere. The crux of the problem, as I see it, lies in the validity of methods of gathering data, or in their subsequent manipulation, if not both." Daubenmire argues that areas affected by human activities or disturbance must be avoided, and that sampling should be done only in "homogeneous vegetation."

Although methodologies for examining continuous variation were well developed in disciplines such as sociology during Gleason's time, they were discovered (in effect, reinvented) by plant ecologists in the 1950s by John Curtis and his students for Wisconsin ecosystems (, Bray and Curtis 1957; Curtis 1959; Curtis and McIntosh 1951) and Robert Whittaker (1956) for the Great Smoky Mountains. These

ecologists argued that the "stratified" sampling of Daubenmire was predestined to find discontinuity on landscapes—sampling should be random. Curtis, Whittaker and their students and associates pioneered a variety of multivariate techniques for posing hypotheses and analyzing such data, and the repertoire of such techniques continues to grow.

In exhaustive reviews, Whittaker (1967, 1975) and McIntosh (1967) effectively put this issue to rest. While it is convenient to speak of community types, largely based on the importance of particular dominant species or growth forms (see, for example, Whittaker 1962), the world does indeed vary continuously. Although organisms modify their environments and competition does indeed influence species' distributions, these facts do not inexorably lead to spatially homogeneous communities that are repeated over and over across the landscape. Nature has not provided us with the basis for a natural classification of communities or ecosystems; any such classification is arbitrary and should be based on the needs and goals of the classifier. I return to the significance of this reality to wilderness management below.

The Ecosystem

In a wonderful paper in which he tried to "set the record straight" on many of the issues discussed above, Arthur G. Tansley (1935) offered up a new term, the ecosystem. He applied this term to mean "the whole *system* [Tansley's emphasis], in the sense of physics, including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment…." Tansley considered ecosystems to be quasi-organisms in the sense that they could be understood by the same principles of physics and chemistry that were in his time the cutting edge of organismal physiology.

Notwithstanding Lindemann's (1942) work on trophic dynamics in lakes, it would be nearly two decades (Odum 1956, 1957; Odum and Odum 1955) before this concept began to influence actual on the ground (or in the water) research, and the brothers Odum clearly led the way. It is not my wish to rehash here the history of the development of ecosystem ecology; excellent reviews are available in Christensen and others (1996), Golley (1993), Hagen (1992) and Pomeroy and Alberts (1988). Comparatively little ecosystem research has actually been focused exclusively on wilderness areas, although comparisons between disturbed and relatively undisturbed areas (as in the paired watersheds of at Hubbard Brook and elsewhere) have been very important indeed. I do wish to assert that several important lessons from ecosystem studies over the past four decades very much condition our current understanding of wilderness and the future role of wilderness for science.

Perhaps the most daunting lesson from our studies of ecosystems is the inescapable reality of the laws of conservation of mass and energy and thermodynamics. At any scale we may choose, ecosystems are necessarily open to inputs and outflows of matter and energy. Energy transformations are such that disorder (entropy) of the universe always increases; local reversal of that trend within an ecosystem depends on the input of energy.

Given these realities, there is no agreement on exactly how an ecosystem ought to bounded. Indeed, the operational definition of ecosystem boundaries is left to the ecosystem ecologist (Christensen and others 1996), who usually defines them based on the ease of measurement or manipulation of inputs, outputs or internal processes. Therefore, the selection of boundaries most often depends on the process of interest—the scale appropriate for processes driven by flows of water (a watershed for example) may be inappropriate for processes driven by other factors.

Wilderness Science and Wilderness Management

Wilderness conservation or preservation, I would argue, focuses on three questions, 1) what should be preserved, 2) what size and form should preserves have and 3) by what means should preserves be managed? It is perhaps debatable whether, over the past century, our scientific understanding of wilderness has shaped or merely justified our answers to these questions. Either way, the impact of science in wilderness on wilderness is powerful.

The question of what to preserve has both a philosophical and an operational dimension. Philosophically, we might ask what should comprise the shopping list? Species? Communities? Habitats? Ecosystems? Landscapes? If we agree that our focus should be on ecosystems and landscapes, we are not likely to find agreement on the items we ought to include on the list. The list of endangered ecosystems constructed by Noss and others (1995) will serve as a starting place for those who see wilderness conservation as a high priority; others will surely see it as "too fine a filter." That nature has not provided us with a natural system of classification of communities, ecosystems or landscapes means that any such list is driven by *a priori* goals and values.

The evolution of our understanding of ecosystem change and ecosystem processes has provided us with important information relevant to the design of wilderness preserves. Unfortunately for much of our system of wilderness parks and preserves, the information came too late. The boundaries of few preserves have been designed based on understanding of the scale of the ecosystem processes that sustain them. Lessons from the Yellowstone fires or the management of endangered species (often top carnivores) is that the areas we have set aside are poorly designed and too small. We are beginning to understand that, in the best of all worlds, we will be able to set aside a small portion of the world as wilderness, and our success in managing it will depend as much on how we manage the surrounding matrix of lands as on our protocols for management within the preserves.

Although early legislation creating wilderness parks focused on "natural and historic" *objects*, we have come to understand that wilderness management is not a simple exercise in museum curation (Christensen 1995), that we must understand and manage the processes that sustain these dynamic systems. When we viewed change as leading inexorably to stable communities, and disturbance as setting that process back, policies and protocols to exclude disturbance seemed appropriate. In a world

driven by regular cycles, our view of what to preserve became more complex, and we recognized that disturbances such as fire and the changes they set in motion needed to be incorporated into wilderness management. In the more complex and uncertain patch mosaic world we now live in, we are beginning to understand that such management can be daunting. We are not only aware that the current state of our knowledge on these dynamics is incomplete and provisional, but we are also hopeful that this is the case.

Over the past decade, "ecosystem management" has been advocated as a means of coping with each of these challenges. Such management attempts to incorporate our understanding of the dynamics of ecosystems and landscapes, the arbitrary nature of boundaries, and the "physics" of the ecosystem (Christensen and others 1996). Perhaps even more important, it seeks to include humans in management in a more realistic and sustainable way (Lackey 1998).

The human dimension of ecosystem management, whether on managed landscapes or in wilderness, has, nonetheless, been far more difficult to articulate. It is clear that we humans are an inescapable part of the biota of virtually any ecosystem on the face of the earth. While we may wish to view wilderness as that part of the earth where we have the least impact, we should not deny our historic and current impacts on even the most pristine landscapes. It is equally clear that ecosystems are open not only to flows of matter and energy, but also to the flows of human values. It is this fact that makes ecosystem management truly daunting. The spatial and temporal domains in which human values are important to an ecosystem are often far different from those relevant to matter and energy. This has been evident in the attempts of management agencies to ensure "stakeholder involvement" in management decisions. Stakeholders are not just those individuals contained within an ecosystem or those directly influenced by the behavior of that ecosystem. By their willingness to support various nongovernmental organizations (whether Wise Use or Earth First) or vote for representatives who set land-use policy, individuals who may never set foot in a wilderness area are nonetheless stakeholders. Given the evolution of global communications and the global market place, human values are transmitted at the speed of light and may have surprising consequences. For example, creation of a carbon trading system within the proposed Kyoto accords may create new and very real economic values for wilderness ecosystems. Changes in those values might well influence the values we set for commodities such as wood fiber, which in turn will likely affect much land management.

Unlike matter and energy, there is no law of conservation for human values, and for this we should be grateful. Old values and views can and do disappear to be replaced by new and hopefully better informed ones. Science in wilderness has played and should continue to play a significant role in this process.

Closing Thoughts: The Evolving Role of Wilderness in Science

During much of this century, wilderness was that part of the world where ecologists went to understand the nature and functioning of ecosystems free of human effects. Even where the focus of research was on ecosystem change following human activities, such as the abandonment of agricultural fields, ecologists sought to study such change as if human influences ceased at the moment of abandonment (for example Oosting 1942). The fallacy of this form of denial was obvious to some early on. While Aldo Leopold (1941) argued that wilderness provides the "base datum for normality" for a "science of land health," he also lamented, in a 1927 letter to the superintendent of Glacier National Park, that "the balance of nature in any strict sense has been upset long ago…. The only option we have is to create a new balance objectively determined in each area in accordance with the intended use of that area." (cited in Knight and Wallace 1989).

I am sure I was not the only ecology Ph.D. candidate working in the 1960s who was admonished by his advisors to avoid working in areas where human influences might confound one's understanding of the true workings of ecosystems. Confident that I had selected such a place for research on the biogeochemical impacts of fire in chaparral, I developed a completely "biocentric" explanation for seasonal pulses of soil nitrate in these shrublands (Christensen 1973). I was more than a little embarrassed when Schlesinger and Hasey (1981) demonstrated that these seasonal dynamics were driven by anthropogenic injections of inorganic nitrogen compounds into the atmosphere over 100 kilometers from my study area.

During the last half of this century, areas where human impacts have been minimal have served as "controls" against which to compare the impacts of human action or disturbance such as in the paired watershed studies at Hubbard Brook (Likens and others 1977). Given the ubiquity of human impacts (such as CO_2 enrichment, air quality degradation and climate change), the concept of a "control" ecosystem without human influence is the ecological equivalent of the frictionless plane in physics. This is not to deny the importance of less disturbed areas for comparative research, but it does emphasize the need to be sure that our interpretations are not confounded by interactions with the growing array of background human influences.

Some argue that, in the time span of at least the past 10 millennia, wilderness absent of human influence is a myth (Christensen 1995; Cronon 1995). We are, after all, certain that the nearly complete loss of the Native American from much of the North American landscape represents the loss of one of the most important top carnivores and agents of change in that landscape during the Holocene. We are only beginning to understand the magnitude of those influences, and we are struggling with how best to incorporate them into our understanding of and vision for the North American wilderness.

Mark Twain wryly commented on a totally unrelated matter that "the researches of many commentators have shed considerable darkness on this subject and should they continue we will surely know nothing." A cynical view of the 100-year history of our research on change might lead us to agree with Twain. We began this century with an elegant theory of change, albeit one driven more by how we would have liked the wild world to operate than one informed by real data. Today, the talk is about temporal and spatial complexity, chaos and uncertainty, and we ecologists (the

discipline accused of calling a shovel a geotome) call this progress. I personally prefer Thomas Huxley's take on this history—what he called the tragedy of science; "the slaying of a beautiful idea by a simple fact." It is probably true that ecologists today are less certain than some of their forebears about exactly how wilderness ecosystems function, but our fundamental understanding of that function has improved by orders of magnitude. That the world is more complex than we thought should come as no surprise. That wilderness has shaped the evolution of our science should also come as no surprise. In the words of Aldo Leopold (1949), "all history consists of successive excursions from a single starting point, to which man returns again and again to organize yet another excursion for durable values. That starting point is wilderness."

References

Billings, W. D. 1950. Vegetation and plant growth as affected by chemically altered rocks in the western Great Basin. Ecology. 31:62-74.

Biswell, H. H. 1967. Forest fire in perspective. Proceedings of the Tall Timbers Fire Ecology Conference. 7: 42-66.

Biswell, H. H.; R. D. Taber; D. W. Hedrick; A. M. Schultz. 1952. Management of chamise brushlands for game in the north coast region of California. California Fish and Game. 38: 453-484.

Bliss, L. C. 1988. Arctic tundra and polar desert biome. In: Barbour, M. G.; W. D. Billings, eds. North American terrestrial vegetation. Cambridge. University of Cambridge Press. 2-32.

Bormann, F. H.; G. E. Likens. 1979. Pattern and process in a forested ecosystem. New York. Springer Verlag. 253 p.

Braun-Blanquet, J. 1932. Plant sociology: the study of plant communities. New York. McGraw-Hill. 439 p.

Bray, J. R.; J. T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecological Monographs. 27: 325-349.

Cain, S. A.; W. T. Penfound. 1938. *Aceretum rubri*: the red maple swamp forest of central Long Island. American Midland Naturalist. 19:390-416.

Cain, S. A.1939. The climax and its complexities. American Midland Naturalist. 21:146-181.

Christensen, N. L. 1973. Fire and the nitrogen cycle in California chaparral. Science. 181: 66-68.

Christensen, N. L. 1985. Shrubland fire regimes and their evolutionary consequences. In: Pickett, S. T. A.; P. S. White, eds. Natural disturbance and patch dymanics. Orlando. Academic Press: 86-99.

Christensen, N.L. 1995. Plants in dynamic environments: is "wilderness management" an oxymoron? In: Schullery, P.; J. D. Varley, eds. Plants and the Environment. Washington, DC. U.S. Department of the Interior, National Park Service. 63-72.

Christensen, N.L.; A. Bartuska; J. H. Brown; S. Carpenter; C. D'Antonio; R. Francis; J. F. Franklin; J. A. MacMahon; R. F. Noss; D. J. Parsons; C. H. Peterson; M. G. Turner; R. G. Woodmansee. 1996. The scientific basis for ecosystem management. Ecological Applications. 6: 665-691.

Clements, F. E. 1904. The development and structure of vegetation. Nebraska University Botanical Survey. 7: 1-175.

Clements, F. E. 1916. Plant succession: an analysis of the development of vegetation. Carnegie Institute of Washington Publication. 242: 1-512.

Clements, F. E. 1932. Nature and structure of the climax. Journal of Ecology. 24: 252-284.

Clements, F. E. 1935. Experimental Ecology in the Public Service. Ecology. 16: 342-363.

Cooper, C. F. 1961. Changes in vegetation, structure, and growth of southwestern pine forests since white establishment. Ecological Monographs. 30: 129-164.

Cooper, W. S. 1916. Plant successions in the Mount Robson Region, British Columbia. Plant World. 19: 211-238.

Cooper, W. S. 1922. The broad-sclerophyll vegetation of California: an ecological study of the chaparral and its related communities. Carnegie Institute of Washington Publication. 319: 1-124.

Cooper, W. S. 1926. The fundamentals of vegetation change. Ecology. 7: 391-413.

Cowles, H. C. 1899. The ecological relations of the vegetation on the sand dunes of Lake Michigan. I. Geographical relations of the dune floras. Botanical Gazette. 27: 95-117, 167-202, 281-308, 361-391.

Cowles, H. C. 1901. The physiographic ecology of Chicago and vicinity; a study of the origin, development, and classification of plant societies. Botanical Gazette. 31: 73-108, 145-182.

Cowles, H. C. 1911. The causes of vegetative cycles. Botanical Gazette. 51: 161-183.

Cowles, H. C. 1919. Review of Clements' "Plant Succession." Botanical Gazette. 68: 477-478.

Cronon, W. 1995. The trouble with wilderness; or, getting back to the wrong nature. In: Cronon, W., ed. Uncommon ground. New York. W. W. Norton & Company. 69-90.

Curtis, J. T.; R. P. McIntosh. 1951. The upland forest continuum in the prairie-forest border region of Wisconsin. Ecology. 32: 476-496.

Curtis, J. T. 1959. The vegetation of Wisconsin: an ordination of plant communities. Madison, Wisconsin. University of Wisconsin Press. 657 p.

Daubenmire, R. 1966. Vegetation: identification of typal communities. Science. 151:291-298.

Garren, K. H. 1943. Effects of fire on vegetation of the southeastern United States. Botanical Review. 9:617-654.

Gleason, H. A. 1926. The individualistic concept of the plant association. Torrey Botanical Club Bulletin. 53: 7-26.

Gleason, H. A. 1939. The individualistic concept of the plant association. The American Midland Naturalist. 21: 92-110.

Golley, F. B. 1993. A history of the ecosystem concept in ecology: more than the sum of the parts. New Haven, Connecticut. Yale University Press. 254 p.

Hagen, J. B. 1992. An entangled bank: the origins of ecosystem ecology. New Brunswick, New Jersey. Rutgers University Press. 245 p.

Hansen, A. A. 1921. The terminology of the ultimate vegetation. Ecology. 2: 125-126.

Harper, R. M. 1911. The relation of climax vegetation to islands and peninsulas. Torrey Botanical Club Bulletin. 38: 515-525.

Harper, R. M. 1914. Geography and vegetation of northern Florida. Florida Geological Survey Annual Report. 6: 163-451.

Harper, R. M. 1940. Fire and Forests. American Botanist. 46: 5-7.

Kilgore, B. M. 1979. The ecological role of fire in Sierran conifer forests: its application to National Park management. Quaternary Research. 3: 496-513.

Knight, D. H.; L. L. Wallace. 1989. The Yellowstone fires—issues in landscape ecology. BioScience. 39: 700-706.

Lackey, R. T. 1998. Seven pillars of ecosystem management. Landscape and Urban Planning. 40: 21-30.

Leopold, A. 1941. Wilderness as a land laboratory. Living Wilderness. 6: 3.

Leopold, A. 1949. A Sand County almanac. New York. Oxford University Press. 226 p.

Levin, S. A.; R. T. Paine. 1974. Disturbance, patch formation, and community structure. Proceedings of the National Academy of Sciences U.S.A. 71. 2744-2747.

Likens, G. E.; F. H. Bormann; R. S. Pierce; J. S. Eaton; N. M. Johnson. 1977. Biogeochemistry of a forested ecosystem. New York. Springer-Verlag. 146 p.

Lindemann, R. L. 1942. The trophic-dynamic aspect of ecology. Ecology. 23: 399-418.

MacArthur, R. H.; E. O. Wilson. 1967. The theory of island biogeography. Princeton, N.J. Princeton University Press. 203 p.

Margalef, D. R. 1963. On certain unifying principles in ecology. American Naturalist. 97: 357-374.

Margalef, D. R. 1968. Perspectives in ecological theory. Chicago. University of Chicago Press. 111 p.

McIntosh, R. P. 1967. The continuum concept of vegetation. Botanical Review. 33: 130-187.

Merriam, C.H. 1898. Live zones and crop zones of the United States. U.S. Biological Survey Bulletin. 10:1-79.

Mutch, R. W. 1970. Wildland fires and ecosystems—a hypothesis. Ecology. 51: 1046-1051.
Noss, R.F.; E. T. LaRoe III; J. M. Scott. 1995. Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. Washington, DC. National Biological Service Biological Report 28.
Odum, E.P. 1969. The strategy of ecosystem development. Science.164:262-270.
Odum, E.P. 1971. Fundamentals of Ecology. Philadelphia, PA. Saunders. 555 p.
Odum, H. T. 1956. Efficiencies, size of organisms, and community structure. Ecology. 37: 592-597.
Odum, H. T. 1957. Trophic structure and productivity of Silver Springs. Florida. Ecological Monographs. 27: 55-112.
Odum, H. T.; E. P. Odum. 1955. Trophic structure and productivity of a windward coral reef community on Eniwetok Atoll. Ecological Monographs. 25: 291-320.
Oosting, H. J. 1942. An ecological analysis of the plant communities of Piedmont, North Carolina. American Midland Naturalist. 28:1-126.
Oosting, H. J. 1948. The study of plant communities: an introduction to plant ecology. San Francisco: Freeman. 389 p.
Paine, R.T. and Simon A. Levin. 1981. Intertidal Landscapes: Disturbance and the Dynamics of Pattern. Ecological Monographs. 51:145-178.
Peters, R. H. 1976. Tautology in evolution and ecology. American Naturalist. 110: 1-12.
Peterson, K. M.; W. D. Billings. 1978 Geomorphic processes and vegetational change along the Meade River sand bluffs. Arctic. 31: 7-23.
Platt, R. B. 1951. An ecological study of the mid-Appalachian shale barrens and of the plants endemic to them. Ecological Monographs. 21:269-300.
Pomeroy, L. R.; Alberts, J. J. 1988. Concepts of ecosystem ecology: a comparative view. New York: Springer-Verlag. 384 p.
Sampson, A. W. 1944. Plant succession on burned chaparral lands in northern California. California Agricultural Experimental Station Bulletin. 685:1-144.
Schlesinger, W. H. ; M. M. Hasey. 1981. Decomposition of Chaparral Shrub Foliage: Losses of Organic and Inorganic Constituents from Deciduous and Evergreen Leaves. Ecology. 62: 762-774.
Sprugel, D. G. 1976. Dynamic structure of wave-regenerated *Abies balsamea* forests in the northeastern United States. Journal of Ecology. 64: 889-911.
Sprugel, D. G. 1984. Density, biomass, productivity, and nutrient cycling changes during stand development in wave-regenerated balsam fir forests. Ecological Monographs. 54: 165-186.
Sutherland, J.P. 1974. Multiple stable points in natural communities. American Naturalist. 108: 859-872.
Tansley, A. G. 1935. The use and abuse of vegetational concepts and terms. Ecology. 16:284-307.
Usher, M. B. 1979. Markovian approaches to ecological succession. Journal of Animal Ecology. 48: 413-426.
Watt, A. S. 1947. Pattern and process in the plant community. Journal of Ecology. 35: 1-22.
Wells, B. W. 1939. A new forest climax: the salt-spray climax of Smith Island, N.C. Torrey Botanical Club Bulletin. 66:629-634.
Wells, B. W. 1942. Ecological problems of the southeastern United States Coastal Plain. Botanical Review. 8:533-561.
Wells, B. W.; I. V. Shunk. 1931. The vegetation and habitat factors of the coarser sands of the North Carolina Coastal Plain; an ecological study. Ecological Monographs. 1: 465-520.
White P. S.; S. T. A. Pickett. 1985. Natural and patch dynamics: an introduction. In: Pickett, S. T. A.; P. S. White, eds. Natural disturbance and patch dymanics. Orlando. Academic Press: 3-13.
Whittaker, R. H. 1953. A consideration of climax theory: the climax as a population and pattern. Ecological Monographs. 23: 41-78.
Whittaker, R. H. 1956. Vegetation of the Great Smoky Mountains. Ecological Monographs. 26: 1-80.
Whittaker, R. H. 1962. Classification of natural communities. Botanical Review. 28: 1-239.
Whittaker, R. H. 1967. Gradient analysis of vegetation. Biological Reviews. 42: 207-264.
Whittaker, R. H. 1975. Communities and Ecosystems (second edition). New York. MacMillan. 385 p.

The Effects of Wilderness Settings on Organized Groups: A State-of-Knowledge Paper

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Abstract—Organized groups present a major use of wilderness resources. The focus of this paper is on the research findings that have emerged over the past 12 years concerning the benefits and effects of participation by groups in wilderness and wilderness-like areas. In general, the majority of research in this area has provided evidence of the beneficial and positive effects of wilderness participation by both individuals and groups. This paper categorizes these benefits and effects into three major variable clusters: self-systems, therapeutic outcomes, and group dynamics. Also included is a discussion of the implications of these findings and issues to managers, educators, and researchers.

> The wilderness gave them their first taste of those rewards and penalties for wise and foolish acts which every [woodsperson] faces daily, but against which civilization has built a thousand buffers (Aldo Leopold).

In a recent issue of Society and Natural Resources, Daniel Payne (1999) talks about the development of environmental policy in North America. He argues that in the early part of the 20th century, (often referred to as the Progressive Era), debates occurred about the natural environment. These debates centered around land allocation, wildlife protection, and the "proper" use of natural resources. He goes on to describe the "second generation" of more recent environmental issues which include pesticide use, global warming and air pollution.

We would propose that there is now a "third generation" of environmentally related issues. These issues focus on the use of natural environments such as wilderness and wilderness-like areas to improve the human condition and that these improvements go beyond the production of commodities or material goods. More specifically, we believe that participation in activities based in wilderness and wilderness-like settings can have profound effects on both groups and individuals. This premise, however, gives rise to a number of questions. If effects are evident, what are they? How do they manifest themselves, and does the setting (wilderness) provide the principal vector for change, or do other confounding variables such as group, activity, or individual attributes?

This paper provides an overview of a sampling of research efforts—methods and findings—conducted since the last Wilderness Research Conference was held in 1985 (Lucas 1987). For an understanding of the research efforts conducted on the wilderness user presented at the 1985 conference, the reader is referred to the following works: Driver, Nash and Haas (1987), Roggenbuck and Lucas (1987), Stankey and Schreyer (1987).

Importance of the Topic

People have been visiting and traveling through wilderness and wilderness-like areas, within the framework of organized groups, since the inception of humankind. It was not until fairly recently however, that wilderness and other undeveloped landscapes were considered to have some redeeming characteristics (Bergon 1980; Jenseth and Lotto 1996; Nash 1982). Indeed, it was not until the advent of the Romantic Era (1700-1800s) that wilderness began to be more widely accepted as a place for possible enjoyment rather than desolation and hardship (Ewert and Hollenhorst, 1990). By the 1990s, the picture had changed completely. Wilderness is now eagerly sought out by millions of visitors and used by a growing number of organizations for personal growth and therapeutic intentions (Easley and others 1990; Gager and others 1998). Friese (1996) reports that there are over 700 organizations offering wilderness programs for personal growth and Gager (1996) suggests that these types of programs are growing at approximately 15 percent per year. While it appears that the rate of visitation to wilderness areas among the general public has slowed (Loomis and others 1999), the use of these lands by organized groups, particularly those seeking specialized outcomes, such as personal growth and development, has grown dramatically.

How the Topic was Studied: Assumptions and Caveats

The wilderness experience and benefits from wilderness-like environments have been widely studied (Driver and others 1987; Lucas 1990). This current analysis examined research studies conducted since 1987 and used the criteria suggested by Driver, Easley, and Passineau (1990): qualification (specification of types of benefits and effects), quantification

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(the magnitude of those effects and benefits) and valuation or relative importance of the benefits.

Given the extent and variety of research efforts done in this area, a delimitation procedure was employed. Essentially, if over 50 studies were conducted on a specific topic associated with the effects of wilderness activities on organized groups the literature search was restricted to refereed literature. If relatively fewer studies were generated, the literature search was expanded to include the Dissertation Abstracts International (DAI), proceedings articles, and other sources of research information.

This review used a number of assumptions and caveats. First, while technically different, the terms wilderness, wilderness-like areas, and wildlands are used interchangeably. Inherent in all three definitions is the component of undeveloped, relatively contiguous areas that are substantially free of significant human impacts.

Second, organized groups was the primary unit of interest. Given the broad spectrum of organizations, it is acknowledged that there is a wide variance of organized groups, often with differing structures, wilderness experiences, and involvement with wilderness areas. For the purpose of this study, organized groups referred to collections of individuals that are part of a larger organization. For example, the organization might be a church group, a wilderness experience group such as the National Outdoor Leadership School (N.O.L.S.) or a group of Scouts. This type of structure differentiates organized groups from a collection of friends that participate in a wilderness experience.

It is also acknowledged that there are a variety of benefits that are possible outcomes from wilderness participation. Within this work, benefits are defined as improved condition or the prevention of a worse condition to an individual or group of individuals (e.g., collection of friends, family, community, nation, etc.) (Driver and Peterson 1987; Lee and Driver 1999). Despite the effort to acquire and review the highest quality literature available, it is freely conceded that some material and studies were probably incorrectly evaluated or missed completely.

In addition, a range of samples and specific variables were examined. A partial listing of these includes the following: marriage and family, informal and formal, educational organizations, environmental organizations, special-focus groups (e.g., business groups) and groups involved with therapeutic applications.

A number of specific variables appeared with some consistency in the literature. These included: mutual support, social interaction, trust, communication, group development, stress reduction and/or coping, recidivism rates, self-systems such as self-concept, perceived and actual competence, decision-making, and group dynamics. Of these specific variables studied, those associated with self-systems were the most numerous.

Finally, there appears to be considerable overlap in the literature among the concepts of wilderness experience, adventure education and challenge programing. In this work, the emphasis was on using wilderness or wildlands as the setting for participation. Thus, a study was not included in this analysis if the participants were not exposed to a wilderness, or wilderness-like environment. For example, ropes courses are now used extensively in numerous programs and numerous research efforts have now examined their effects. Under the guidelines for this paper, studies using only ropes courses were not included in the analysis. In another example, Outward Bound programs utilize a variety of undeveloped landscapes and unless a study indicated that an urban or developed site was the location of the program, these studies were included in the analysis.

Challenges of Conducting Research on Wilderness Groups

It is difficult to conduct research with organized wilderness group programs and the researcher faces a number of challenges in conducting research that is valid and reliable, yet not overly intrusive to the participants. The first challenge is the environment. The very same environmental factors that make a wilderness trip exciting, unique, and challenging make research difficult. It often takes a great deal of effort to carry and protect data collection instruments into wilderness. Inclement weather provides challenges in keeping survey forms and paper-pencil test instruments dry and usable. Carrying tape recorders or video recorders in packs can be arduous in rough terrain. Keeping instruments dry and secure is a trying endeavor in rain, snow, on white-water rivers, on glaciers, and in sea kayaks. Another challenge is the fact that most groups in these programs are small, around 6-10 members to encourage positive group dynamics, and also because of minimum-impact group size regulations in many wilderness areas. This means sample sizes are small, and attempts to increase sample size means working with a number of groups spread out over time.

The logistics and schedules of wilderness group programs also present a challenge. Participants often are not an intact group, and come to an organization or the trailhead from all over the world. The logistics of getting participants outfitted with necessary equipment, oriented to the organization and the trip, and instructed on the basics of safety and group movement into the wilderness leave very little time or energy for data collection at the beginning of a program. This is often the case at the end of the program as well, when participants have to turn in gear, arrange departure schedules and logistics, conduct agency mandated evaluations, and attempt to re-enter a hectic world that seemed held a bay while they were in a wilderness environment as an intact group. Most organized wilderness group programs also have a number of organizationally identified goals that are to be addressed throughout the program. These goals are often comported by program activities during the wilderness trip. If the researcher chooses to study variables that may not be directly related to these program goals, there may be little time available during the trip to address the those interests.

Another major challenge faced by the researcher is to be non-intrusive to the group wilderness experience. As groups are usually small in these programs, a researcher may have a difficult time becoming integrated sufficiently with the group to collect data. Yet it is important that the researcher not be integrated to such an extent that the he/she begins to influence the dynamics of the group and the experience of the participants. Some research methods can be intrusive and negatively influence the wilderness experience. Not only does that potential pose a bias problem for the data

collected, but it may also create a public relations or marketing problem for the organization. Participants may begin to ask themselves, "Why do I have to put up with this research stuff? I came on this trip to enjoy the wilderness."

Group wilderness programs put participants in a milieu of heightened emotions and this can be an additional challenge to the researcher. The emotional environment is one of the positive aspects of these programs, and can lead to major personal development and insights. But intensified emotions can also make participants feel that attempts to research and document what is happening to them somehow denigrates or lessens the quality of their experience. Participants may want to avoid verbalizing elements of their experience to a researcher, particularly one they perceive as not being a complete member of their immediate group on the wilderness experience. This can lead to less intense or accurate descriptions of the participants' experience as they may not want to reveal the true depth of their experience to an outsider.

Another difficulty in ascertaining benefits from wilderness participation lies in the internal motivations of the wilderness participant. Borstelman (1977) made a significant finding from his study of Outward Bound students and instructors that continues to vex the entire field of beneficial effects from outdoor and wilderness programs. Essentially, he found that students who attended these types of courses were often "ready to change," and this attitude was possibly what created the majority of positive changes observed in various research studies. He termed this state, the "readiness to change syndrome." If true, his findings cast doubt on the effectiveness of any setting or self-reported finding, or as Ewert (1982) states, "[readiness to change] would place a pallor of skepticism on any statistically significant results." Consequently, are many reported changes due to participation in wilderness or, as previously suggested, are they a manifestation of another, more covert variable such as an individual's initial motivation for participation?

Finally, as mentioned previously, it was difficult to distinguish the effects on an individual from the effects on an individual as a member of a group. That is, while the individual was usually the unit of measurement, few of the studies investigated were able to discern the effect of the group upon the individual outcomes. Thus, from a theoretical as well as practical standpoint, potentially confounding effects of group influence, instructor/leader traits and impacts on participants, and type and structure of the experience were often nested within the larger parameters under study such as self-systems. As a result, from a scientific perspective, it is difficult to ascertain whether any observed changes or impacts were a result of the wilderness or simple, manifest outcomes from the type of program, the group, or other non-wilderness setting vectors. Thus, the question of whether the presence of wilderness "made the difference" remains an enigma, in many cases.

History of the Topic

Evolving Research Themes and Methods

Early research on the benefits of organized groups using wilderness focused almost exclusively on the individual, documenting benefits and/or changes to the individual as a result of the organized group participating together in a wilderness context. This is still the case in many of the therapeutic programs that use wilderness as a medium for treatment of individual conditions. But there is now an increasing research interest and focus on the influences these wilderness experiences have and can have on the group itself. Research is now beginning to shift toward identifying, documenting and measuring the influences wilderness group experiences can have on group variables, including: group development, group cohesion, trust, social relations and family functioning. Wilderness group experiences offer a rich setting and a set of powerful conditions for various elements of group development. The growing emphasis on cooperative and collaborative group functioning in organizations ranging from corporate groups, to schools, to treatment centers seems to be driving this increased interest in group development and group functioning. Research on group development in organized wilderness group programs is just beginning and will probably continue to develop as a major research theme.

As documented in other sections of this paper, the research designs and methods used in studying wilderness group programs are becoming more diverse and innovative. Early research on groups in wilderness focused on using standardized psychological testing instruments to attempt to document individual changes that could be attributed to participation in the wilderness group programs. This was due, in part, to legitimize the research as scientific and to legitimize the programs as being clinical and effective in precipitating individual improvement. Standardized psychological tests, such as the Tennessee Self-Concept Scale, have been used extensively in a variety of programs and are still used quite extensively in therapeutic and clinical programs. A number of new and more appropriate and accurate standardized testing instruments are now being used to analyzing these therapeutic benefits of organized wilderness programs (for examples, see Bandoroff and Scherer 1994; Gillis and Simpson 1991; Kelley and others 1997; Russell and others 1998) .

Other non-clinical programs, as well as a number of clinical programs, are now being studied using a much wider range of research designs and methods. (See Implications for Researchers for citations). The current research emphasis on organized wilderness groups is attempting to go beyond identifying the benefits, the *what* of the programs and experiences. Research is now attempting to move more into trying to increase the level of understanding of the *how* and the *why* of these experiences. How do people and groups grow or receive benefits from group participation in an organized wilderness program? What is it about the program that creates an environment for that growth and why does that growth take place in a group environment in a wilderness setting?

Evolution of the Theoretical Frameworks in Group Benefits

There are numerous examples of the early use of wilderness for therapeutic as well as recreational endeavors. Some examples of these early organizations and groups are provided by Davis-Berman and Berman (1994) and include the following: the Gunnery School for Boys (1861), the Fresh

Air Camps (1871), the Boy Scouts (1908) and Girl Scouts (1912) and the "Tent Therapy Programs" (1901).

It was not until 1940s, however, that two programs emerged that would have lasting impact not only on the therapeutic applications of wilderness and wildlands, but also impact the use of wilderness today. These programs were the Salesmanship Club of Dallas and Outward Bound. In both cases, systematic attempts were made to design programs that used the natural environment as a mechanism to teach specific learning and personal objectives. Of the two, Outward Bound became the most widely modeled and serves today as the theoretical model for most organized groups using the wilderness with therapeutic intent. Based on the work of Walsh and Golins (1975) this model of participant change is illustrated in Figure 1.

More recently, Gager (1977) has expanded on the Walsh and Golins model by a more precise specification of the various change agents. Figure 2 illustrates that model.

Although not all wilderness-based programs ascribe to the models by Walsh and Golins (1975) or Gager (1977), these models provide the theoretical basis for many if not most such programs. Thus, the wilderness experience may provide a mechanism for change by providing the unique physical setting from which the individual, as part of a unique social setting (the group), goes through a series of physical and mental challenges and is subject to feedback from the instructor/leader and/or other individuals in the group in addition to personal reflection. Following this, the individual may experience a set of values, behaviors, attitudes, etc. that are different from before the wilderness experience. The question remains whether this process or any other similar change model actually works.

Research Findings

One of the presenters at this conference, Dr. John Hendee, stated in one of his presentations that "Wilderness is used for growing people, as well as growing natural resources." Research over the past three decades suggests that this is true. Wilderness is being used extensively as a place and as an idea to help individuals and groups to grow. A variety of group types utilize wilderness for group and individual growth and development. The research findings that follow are organized into the types of variables and groups studied in group research. The variables include self and systems growth and group dynamics. The group types included in the discussion of variables and research results are: (a) formal groups like Outward Bound the National Outdoor Leadership School; (b) wilderness oriented camps and programs like Boy Scouts and YMCA/YWCA, and other similar programs; (c) informal groups like private personal growth programs (non-profit and for profit); (d) church and youth groups; and (e) educational groups like university classes and outdoor programs, and public and private schools. The research results for wilderness therapy groups and for special-focus groups are presented by group type. The special-focus groups reported in this document are all-women programs, programs that include persons with a variety of disabilities, and wilderness therapy groups including youth with problem behaviors, psychiatric treatment groups, and family therapy groups.

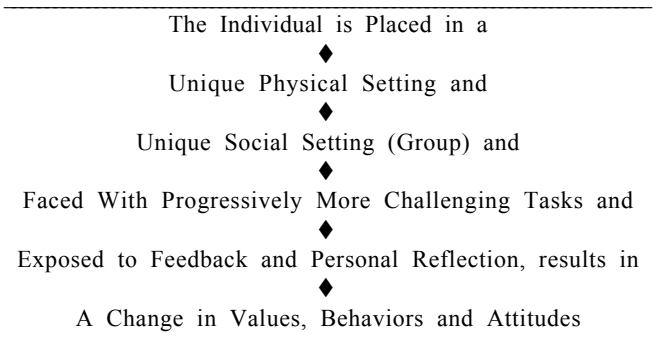

Figure 1—Theoretical model of participant change.

Research Findings by Variables

Self Systems—As previously described, self-systems research generated the largest number of studies reported in the literature. Within this context, self-systems generally refer to a body of knowledge and beliefs that an individual holds about themselves and it is developed through experience and comparison with others (Baumeister 1998). The related terms of self-concept and self-esteem can be defined, respectively, as "an individual's perception of him or herself including personal abilities, appearance, and performance" (Curry and Johnson 1990) and the judgments and attitudes one holds about him or herself (Baumeister 1998).

In general, the literature provided a pattern of positive and beneficial change that is fairly predictable. Usually, younger individuals experienced a "readiness to change" attitude; and those who were female reported greater changes in self-systems than their counterparts. Reported changes in actual behavior and the durability of any of the changes

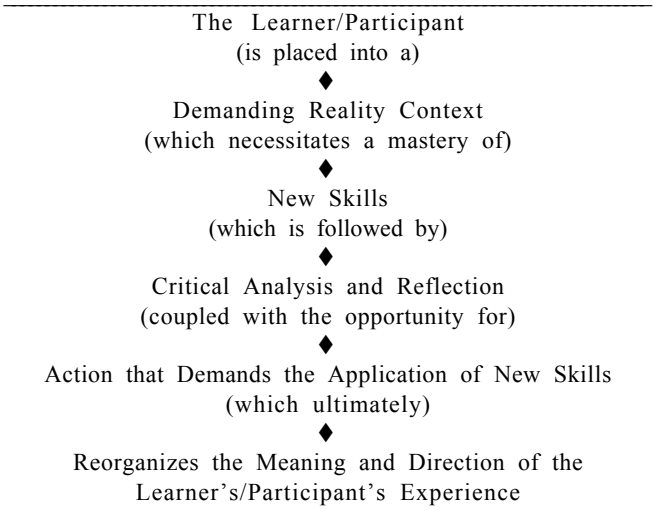

Figure 2—Gager's model of participant change.

from participation in a wilderness experience were less evident. For example, a number of researchers now suggest that how participants perceive the wilderness experience and what factors, such as personality, influence that perception are the least understood areas of research in these types of experiences (Kaplan and Talbot 1983; Scherl 1988). Thus, any conclusions about the effects of the wilderness experience on a construct as complex as the self-system are bound to be vulnerable to questions of validity and comprehensiveness of the variable set.

Extending this thought, Marsh and others (1986) proposed that while self-concept has been studied as a relatively unidimensional construct, more recent evidence support a multi-dimensionality aspect. They studied the effects of participation in a wilderness-based experience through Outward Bound on specific facets of self-concept rather than as one generalized concept. Using a multiple-time-series design for three different times, they observed increases in various specific aspects of self-concept. In a follow-up study, Marsh and others (1986) included an 18 post-post measurement and found additional support for the efficacy of these types of programs in positively influencing specific aspects of the self-concept. They also found that this effect was "durable," in the sense that specific changes to the self-concept were noted 18 months after the end of the course. In related work, Hattie and others (1997) performed a meta-analysis on the effects of adventure programs on a diverse array of outcomes including self-systems and found significant effect sizes for immediate, short term and long term assessments. Not surprisingly, given the wide variety of programs, there was substantial variance in outcomes as a function of program, age of participant, etc.

Gillett and his colleagues (1991) also looked at self-concept as a multi-dimension construct in their investigation of the effects of wilderness camping and hiking on self-concept and environmental knowledge and attitudes of twelfth grade students. Statistical analysis of the pre and posttest scores using the Tennessee Self-Concept Scale (TSCS) and the Coopersmith Self-Esteem Inventory (SEI) revealed a significant increase on three of the ten measures of self-concept for the TSCS and two of the five measures of the SEI. They found no change in environmental attitude when compared to a control group and significant change in environmental knowledge in the experimental group. These findings argue against the claims made by Simpson (1985), who suggested that short-term experiences, like most wilderness outings, are relatively ineffectual in changing the environmental ethics of the participants.

There is one additional and interesting note regarding the SEI measurement used by the researchers. The SEI utilizes a Lie scale as part of the measuring protocol. The researchers in this study found that participants generally answered the instrument items truthfully, thus arguing against the argument made by Ewert and Baker (1999) that participants in many wilderness and environment-related studies are influenced by the wording of the questionnaire or social-based pressures to falsify their response.

Luckner (1989) used a non-traditional population when studying the effects of outdoor adventure education participation upon hearing-impaired individuals through a 10-day winter ski trip. Using a pre-post, control group design with two instruments (Culture-Free Self-Esteem Inventory and the Semantic Differential Scale of Self-Concept), he found significant positive changes in the treatment group. Furthermore, he found that these differences persisted through a two-month follow-up measurement. Luckner (1989) concluded that when combined with the interpersonal and supportive context of group interaction, outdoor adventure experiences, such as wilderness programs, can provide an effective platform for promoting self-concept change.

Related to the construct of self-systems, Kellert (1999) found that participation in three wilderness-based programs (Outward Bound, National Outdoor Leadership School and the Student Conservation Association) produced a number of significant changes. A sampling of these changes included: a life-changing event, increased interest in school, physical and mental fitness, positive behavioral changes and a stronger commitment to conservation and the environment. Kellert (1999) also found that many of these changes had some durability and persisted beyond the end of the course.

Another construct in the category of self-system is self-efficacy which was examined by Propst and Koesler (1998). As defined by Bandura (1977), self-efficacy refers to personal judgments of one's abilities and capability to act in situations that may be novel, unpredictable and potentially stressful (such as wilderness tripping). Using an "untreated control group pre/post test design," Propst and Koesler (1998) found that participation in an outdoor adventure trip increased levels of self-efficacy both immediately after and one-year after the course. They also found differences in efficacy statements as a function of gender immediately after the course, but these differences were not evident in the one-year follow-up. See Neill (1997) for a synopsis of the effects of gender on outdoor education experiences.

Several documents categorize and summarize many of the research findings and studies recently done on wilderness participation. These include studies in the development of adventure and wilderness therapy (Itin 1998), use of wilderness for personal growth (Friese and others 1995), and the use of wilderness for therapy and education (Easley and others 1990).

Group Dynamics and Development—Increasingly, the wilderness has become a place where a group goes to work on being a group. That is, organizations from a wide spectrum of business, church, military, community, and other groups, now use the wilderness setting as a place to develop teamwork, intra-group trust, improved communication, risk taking and overall functioning as a team (Smith and others 1992). Other group dynamics issues typically addressed dealt through wilderness participation involve decision-making, conflict resolution and organizational structuring (Graham 1997).

Despite the importance and popularity of the issues associated with group dynamics, there have been relatively few systematic studies done under the rubric of organized groups in wilderness settings. As stated earlier, it is difficult to distinguish between group effects and individual effects. What studies have been done have usually demonstrated increases in communication between group members, increased trust and willingness to take risks and increased group identity.

For example, Oakes and others (1995) used a wilderness setting and an Outward Bound program to study the

phenomena of familiarity and in-group homogeneity. Their findings revealed, as predicted, that as the group progressed through their Outward Bound course they perceived each other as more alike than different. Given the nature of the wilderness setting and the goals of most Outward Bound programs (such as expected cooperation, supportiveness, and openness), the results seemed to suggest more about the efficacy of the program than the setting.

In a similar manner, Sachs and Miller (1992) examined the effects of a wilderness experience on the social interactions and expectations of a group of behaviorally disordered adolescents. Using a pre/post/post control group design, the researchers found a significant positive increase in the cooperative behavior of the wilderness participants. This change persisted one month after the course but was not significantly different from the control group at this stage.

Ewert and Heywood (1991) examined the impacts of an Outward Bound course on group development. Using Jones and Bearley's (1986) Group Development Assessment Questionnaire, increases from pre to post scores were noted on the sub-variables of orientation to the group, group organization, cohesion, and interdependency. Moreover, decreases were noted in the sub-variables of difficulty in problem-solving and dependency. Clearly, in this case, the program and possibly the setting were effective in strengthening the groups studied.

Taking a more extreme approach, however, Leon and others (1994) examined the effects on the group from a 61-day trek across Siberia. Measurements from this 12-person Soviet-American team revealed that group cohesion tended to break down over time, during the stops at various towns and in the perceived unfairness of tasks, both in terms of group feelings and functioning.

In a later study, examining two Australian teams on 100-day traverses of the Antarctic (Wood and others, 1999), results were somewhat similar. Feelings about the team tended to break down over time and there was much variance in how individual members reacted to group goals and stress.

The previous two studies illustrate an interesting point about group dynamics in wilderness settings. Short-term wilderness experiences appear to be useful in building team morale, cohesiveness and functioning. This appears to be particularly true if the tasks are not too demanding or stress-producing. Add a great deal of stress through environmental conditions or difficulties encountered and variables such as group cohesion and functioning tend to diminish. If true, the implication is clear: Wilderness experiences work to build groups as long as the trip is not too long, too stressful or too demanding. Cross the line of demands and challenges and a functioning group with effective group dynamics tends to diminish in effectiveness, functioning, and individual morale.

Research Findings by Group Type

As previously described, the authors of this paper were challenged by how to present a summary of the research literature on wilderness groups. For example, should the summary be organized according to variables or group type? For clarity, given the range of group types, program goals, and clients, the research findings were organized by variables for formal groups like Outward Bound, NOLS, wilderness camps and programs; informal groups such as private personal growth programs, church and youth groups; and educational groups.

Given, that specialized groups such as those for women, for persons with disabilities and therapeutic groups are different enough from other wilderness groups and programs, the findings from research done on these groups is presented by group type. Those in the practice of leading and managing these types of groups often see the above mentioned groups as significantly different from most other wilderness group programs, particularly in areas such as program goals, group organization and structure, and participant behaviors. In addition, these programs are often targeted at addressing specialized variables such as recidivism, social integration, empowerment, level of substance abuse, and mental health. Thus, those in specialized group and wilderness therapy practice often search for research results according to group type. To facilitate that search, the following research results in specialized and therapeutic groups are presented by group type.

Persons with Disabilities—Wilderness groups that include people with disabilities usually are of two types: segregated groups made up primarily of people with disabilities and integrated groups that include people with and without disabilities. Groups and programs that include people with disabilities have been using wilderness for individual and group development for a number of years. Wilderness Inquiry, Inc. of Minneapolis, the largest integrated wilderness program, has been taking integrated groups to wilderness since 1978.

Reviews of the research literature have summarized the psychological, social and mental health benefits of wilderness group experiences for people with disabilities (McAvoy and others 1995; Robb and Ewert 1987). These benefits include increased self-concept, self-esteem, and self-fulfillment, personal growth, increased leisure skills, increased social adjustment and cooperation, enhanced body image and positive behavior change.

Although little current research focuses on people with disabilities and wilderness, what research does exist over the past 10 years has concentrated on integrated groups. Research by McAvoy and others (1989) found that people with disabilities in integrated wilderness group programs had positive attitude and lifestyle changes, increased outdoor recreation skills, increased social relationships, increased willingness to take risks and higher feelings of self-efficacy. People with disabilities in this study reported that these benefits were transferred to other aspects of their lives after the wilderness experience. The persons without disabilities in this integrated program reported increased levels of understanding of the capabilities of persons with disabilities, more positive attitudes about people with disabilities and increased tolerance of differences among people. These programmatic outcomes are important indications that these programs are achieving one of their goals—of increasing general social integration and tolerance for differences as a result of participation together in a wilderness program in a wilderness environment (McAvoy and others 1989; McAvoy and others 1995).

A more recent study by Anderson and others (1997) confirmed many of the above benefits. This study also found that specific training to improve the outdoor recreation skill level of participants with disabilities effectively assisted in the integration process on the trip, and that these participants continued to use these outdoor skills (canoeing and camping) well after their wilderness experience. Other benefits included increased sensitivity to the needs of others, increased sense of priorities and an increased respect for nature. The people with disabilities also indicated that wilderness provides a unique contribution to the attainment of these benefits. They reported that wilderness seems to intensify and focus personal efforts, which produces a positive impact on group development and increases the social integration of the group. The wilderness environment is important in helping participants come together and perform as a functioning group. This study used journal analysis and interviews to collect part of the data. The theme of "wilderness" appeared repeatedly throughout these journals and interview transcripts.

A disability group that has received little attention in wilderness group research is people with developmental disabilities. This group would include persons with mental retardation, autism and cognitive disabilities. This is a challenging group to study because it is difficult to use self-reporting instruments due to the cognitive and verbal limitations of many participants in these programs. The few studies in the literature generally indicate increases in variables like locus of control and self-esteem from pre to post-testing, but these positive changes are often not maintained over time (Herbert 1998). The studies also have small populations, making application to a broader set of participants difficult. For example, Robinson (1991) found modest gains in self-concept for a small group (4) of mildly "developmentally challenged" young adults in a program based in provincial parks of Ontario.

Rose and Massey (1993) used unique program and research methods to assess a number of potential benefits for a small group (7) of adults with severe cognitive disabilities participating in an expedition on Mount Blanc in the French Alps. Due to the low level of communication possible with the participants in this study, the researchers used interviews with participants who had a primary relationship with the study subjects on the expedition, interviews with staff and volunteers, analysis of detailed diaries kept by staff and the researcher, as well as video tape to document engagement levels of the study subjects. The qualitative results indicate the study participants experienced an enhanced sense of accomplishment, cooperation, trust, self esteem, role reversal, increased fitness level and increased problem solving ability. This program included an extensive training program prior to the expedition, and it is difficult to determine if the benefits resulted from the expedition itself, or the combination of the training and the expedition. The level of involvement of the participants with disabilities, as well as the environment in which they experienced the expedition, would suggest that the training component had as much influence on the achievement of benefits as the expedition itself. There are methodological limitations in this study, but the methods used by these researchers are an interesting and innovative attempt to document the benefits of this type of group in which self-reporting of outcomes is such a challenge.

All-Women Wilderness Groups—All-Women Wilderness Groups are usually programs where groups of women are led by other women into wilderness to achieve specific benefits and outcomes. A number of wilderness program practitioners and scholars have written about the potential benefits of wilderness for women (Henderson 1996) and the benefits of all-women wilderness programs (Asher and others 1994; Mitten 1994; Powch 1994). There have been few studies that actually document the benefits, and many of the studies have been qualitative that makes it difficult to generalize results. However, the literature does suggest these programs can produce important and pervasive benefits for participants. These benefits are gained as individuals work together as a group to successfully meet the challenges of wilderness. This group process produces benefits that include increased self-esteem, self-efficacy and empowerment (Hornibrook and others 1997; Pohl 1998).

Due to socially imposed and perceived constraints, some women are turning to all-women wilderness programs to gain a sense of empowerment, a sense that they have the freedom and the capability to take action to improve their life situation. Some women have been socialized to believe they do not have the necessary skills or capabilities to participate in outdoor recreation activities associated with wilderness, thus, participating in wilderness programs is a source of empowerment for them (Mitten, 1994; Pohl 1998). Wilderness can be a unique environment for empowerment for women because it provides a neutral environment that is not cluttered with socially imposed role expectations. Wilderness offers immediate feedback on decisions and actions, evenhandedness of consequences and a feeling of connecting to the earth and its forces (Powch 1994).

In her in-depth interviews with women who had been involved in wilderness for various lengths of time, Pohl (1998) found that wilderness recreation can lead to increased self-sufficiency, empowerment, problem solving skills, connection to others, and mental clarity. Moreover, Pohl's study suggests all-women groups can be effective in creating beneficial outcomes because participants believed this type of group was more accepting, supportive, and less threatening than groups that include men and women together. In an integrated wilderness group, men seem to dominate the skill areas. But, in an all-womens group there were increased opportunities to learn and practice outdoor skills. Fredrickson and Anderson (1999) found that participants in all-women's wilderness groups experienced spiritual benefits and spiritual growth. This was a theme that also appeared in Pohl's interviews. These programs offered the opportunity for participants to connect deeply with the natural environment on a personal and spiritual level.

The major quantitative study of the benefits and motivations of all-women programs is the Hornibrook and others (1997) study, based on 273 respondents to a survey of Woodswomen, Inc. (Minneapolis, MN) participants. The most important motivations for participating in a variety of wilderness-based programs were: the fact that it was a program exclusive to women; the opportunity to "merge" with nature; participating in physical activity; having a new

experience; and the non-competitive nature of the all-women program. The major outcomes or benefits achieved by the participants were an increased belief in themselves and a sense of pride in accomplishment. Another major outcome was the desire to participate again in an all-women wilderness program. The participants commented frequently in the open-ended responses that they attributed their positive experiences to "…a safe, non-competitive atmosphere, the cooperation between participants, the commonality among the women, the extraordinary leadership, and the opportunity to know different women" (Hornibrook and others 1997).

There seems to be general agreement in the literature that participants in all-women wilderness programs do experience the benefits described above. But there is little information on how wilderness actually contributes to the benefits and outcomes of these programs for these groups.

Wilderness Therapeutic Groups—Wilderness therapy is a part of a larger service system called adventure therapy. Adventure therapy has been defined as a set of adventure activities used to enhance therapeutic assessment and treatment. Adventure therapy is often used to enhance established treatment approaches because it provides a rich therapeutic environment for personal change (Gass 1993). The major elements of adventure therapy are an action-centered therapy, in an unfamiliar environment, where there is the climate of change and where personal and professional assessment can take place. Adventure therapy focuses on small group development, genuine community and successful rather than dysfunctional behavior. The role of the therapist changes from the passive role in traditional therapies to an active role in adventure therapy (Gass 1993).

Wilderness therapy is adventure therapy that occurs in remote wilderness or wildland areas and consists of small-group, multiple day experiences where the group remains relatively intact for the duration of the program. While most of the therapy happens in the context of the experiences, there is often follow-up and transition therapy in some programs. The combination of the wilderness environment and the therapeutic modality constitute the wilderness therapy milieu. These programs usually use a combination of generic group therapy and group systems models, along with interpersonal behavior therapy methods. As members of the group live and interact together as a living community in an isolated natural environment, it creates a situation in which participants have experience the natural consequences of their behaviors (Crisp 1998). Crisp defines wilderness therapy as, "…[involving] modified group psychotherapy applied and integrated into a wilderness activity setting." The wilderness therapists' role is to "…facilitate the process by which a person engages the wilderness, either alone or with others, and derives healing from that interaction" (Powch 1994).

Determining the number and focus of wilderness therapy programs depends on the definitions used to classify programs and approaches. Friese and others (1998) define "Wilderness Experience Programs" (WEP) as those that use wilderness or wildlands for personal growth, therapy, rehabilitation, education and leadership development. Their national survey of 700 potential programs identified at least 266 WEPs in the United States. Russell and Hendee (1999) have identified 38 wilderness therapy programs in the United States. Davis-Berman and others (1994) conducted a national survey of professionals in experiential education and found 31 wilderness therapy programs. Most served adolescents, and the categories of programs included: mental health programs, court programs, school programs, health programs and enrichment programs.

Two excellent reviews of the research in adventure therapy (including wilderness therapy) have been written by Gillis (1992) and Gillis and Thomsen (1996). The reader is urged to consult those reviews for specific information on research results and directions in adventure therapy research. Another recent publication from the proceedings of an international conference on adventure therapy (Itin 1998), offers papers on best practices in adventure therapy, as well as information on outcomes of selected programs.

The following discussion of research findings in wilderness therapy groups and programs is divided into three categories: youth-problem behavior groups, psychiatric treatment groups and wilderness family therapy groups. It is difficult to separate studies according to any category system because some studies cover more than one group type and because some groups include more than one of these categories of participants. Within the youth problem-behavior group discussed below is included discussion of youth-at-risk and youth who have been adjudicated and are part of the criminal justice system.

Youth-Problem Behaviors— Wilderness therapy programs primarily serve adolescents. Cooley (1998) estimates that approximately 10,000 adolescents are served each year in wilderness therapy programs in the United States. Although somewhat of an oversimplification, there are generally two categories of programs within the "youth-problem behaviors" category of programs and groups. One group is often termed "youth-at-risk" although many professionals in the youth development field will argue that all youth in the United States are "at-risk." This first group of youth have the following characteristics: They are often failing at school or dropping out of school, they are abusing or are addicted to drugs, and they are often in defiance of parental and community authorities (Russell and others 1998). The youth in the first category may not have serious psychiatric problems and they may not yet be a part of the juvenile justice system.

Research by Russell and others (1998) on a sample of programs serving youth with problem behaviors has indicated that these wilderness therapy programs result in increased self-concept, self-esteem and self-efficacy which leads to a sense of personal power and motivation to take control and responsibility for their lives. The participants also learned how to communicate with others. Since the programs studied were affiliated with the Federal Job Corps program, the researchers were interested in benefits that related to employability. They found that participation in the wilderness programs increased the length of participation in the Job Corps program, which experts believe leads to a decrease in the incidence of criminal behavior, a decrease in substance abuse and an increase in employability. Neill and Heubeck (1998) found that participation in a nine day wilderness program for at-risk youth resulted in more productive coping styles and less non-productive coping styles.

Much of the research in this category of programs is reported only in dissertations, and these studies often have some methodological limitations. Fried (1994) found that participation of at-risk adolescents in a 22-day wilderness program resulted in higher self-concept, higher perception of control and higher levels of perceived competence among the participants. Wichmann (1991) found that problem solving skills increased among adolescents who participated in a 30-day wilderness course, and that interpersonal problem solving level is predictive of asocial behavior. Sale (1993) found that participation in a six month wilderness adventure education program resulted in ego development and increased self-concept. Sveen and Denholm (1997) found that adolescents who participated in an Australian wilderness-based developmental program based on the Outward Bound model showed increased self-esteem and self-actualization. This finding was particularly evident in female participants. However, the body image score was found to be lower after participation. A 12-month follow-up indicated major decreases in the number of offenses committed by the 62 participants in the program, and the number of those committing the offenses also dropped markedly.

A second category of programs with youth with problem behaviors are those aimed at juvenile offenders who are referred by the courts. There are a number of dissertation studies and other studies in the literature that describe various programs, but there is little reported research on the impacts of these programs on juvenile offenders. Gillis and Simpson (1991) found that an adventure-based therapy approach was effective in reducing conduct-disordered behavior associated with delinquency and drug use by court-involved youth. They found that participants had decreased levels of depression, obsessive compulsive behavior, disorganized thinking, manic excitement and anxiety as a result of participation in the program. Their findings suggest that action-oriented, adventure-based therapy may be helpful in allowing adolescents to become more insightful and to benefit from more traditional forms of treatment. In an older study, Traynelis- Yurek and Giacobbe (1988) found that the length of stay in a residential program for male juvenile offenders which included a wilderness trip component was positively related to lower recidivism rates.

Minor and Elrod (1994) and Elrod & Minor (1992) studied the effects of a program which consisted of job preparation workshops, an outdoor/wilderness experience and family skill building workshops on juveniles on probation for delinquent and/or status offenses. They studied self-concept, locus of control and perceptions of the juvenile justice system. They found no significant increases in any of these variables as a result of program participation. Speculating on why there were no significant gains they cited lack of participation by the families in the family workshops, poorly designed job skills training, and the intensity and duration of the experience. This program only included a three-day wilderness program as part of the overall three-month program.

Eggleston (1998) studied the effects of a one-month wilderness program on at-risk Maori youth who had previous criminal records and had suffered physical or psychological abuse. The program occurred on a remote island. Theme analysis of interviews found the experience increased respect, communication skills and relationships for most participants. Most also reported feeling more in touch with their culture. Roberts and Camasso's study (1991) presented an elaborate rationale for a wilderness-based program for youth-at-risk. They compared the costs and recidivism rates of typical family therapy participants with participants in a wilderness youth program for at-risk youth. When considering the recidivism rates, the wilderness youth program was significantly more cost effective.

Psychiatric Wilderness Treatment Groups—Wilderness therapy programs are used to both assess and treat psychiatric patients. Wilderness therapists believe wilderness trip programs can be an excellent opportunity to observe a patient and determine the nature and extent of their psychiatric difficulties (Gass 1993). These therapists believe these programs can be effective in assessment because participants must live and interact within a community (the wilderness group), adapt to new situations and engage their mental-physical-emotional selves in meeting the challenges of wilderness living; they are also away from other influences that may negatively influence their sense of reality. McCord (1995) used psychological testing with a wilderness-based residential treatment program to assess adolescents. McCord found this to be an effective way to assess adolescents in treatment and was able to assign patients to distinct treatment groups as a result.

Crisp (1998) reported on the results of using a wilderness therapy program for treatment of adolescents with severe mental health issues related to physical and psychological abuse, mental illness, substance abuse or school refusal. Crisp found that participation in a 10-week treatment program with two 4-5 day wilderness expeditions resulted in a decrease in behavior difficulties and an increase in school attendance. Berman and Anton (1988) studied adolescent psychiatric inpatients who were either withdrawn or acting out. The program consisted of outdoor skills training followed by either a seven or nine day wilderness group program experience. They found that patient symptoms decreased as a result of the program, with the most rapid decrease occurring on the wilderness phase of the program. They concluded that this is a viable treatment modality for moderately disturbed adolescent patients.

Kelley and others (1997) studied 79 male and female adults diagnosed with schizophrenia, affective disorders or schizoaffective disorder. They found that a wilderness therapy program of weekly day-long wildland outings for outdoor recreation activities (climbing, canoeing, caving, biking) resulted in increased levels of self-efficacy and self-esteem; weaker results were found for decreasing anxiety and depression. No effects were found in self-reported psychiatric symptoms. However, Pawlowski and others (1993) studied hospitalized patients with schizophrenia and bi-polar disorders in a wilderness therapy program and found a decrease in symptoms and a decrease in hospital re-admission.

Wilderness therapy has been used with psychiatric patients for a number of years. Like many other areas of wilderness therapy, research with these groups is difficult, and the studies reported in the literature often have a number of limitations. But psychiatric wilderness therapy probably has the largest body of wilderness therapy work reported in the literature. Wilderness therapy programs appear to be effective in the psychiatric treatment of

moderately disturbed patients. A summary of the research results indicates that these programs benefit psychiatric patients through increases in levels of self-concept, self-esteem and self efficacy; increases in levels of locus of control (the expectation that powerful others and chance would have less control in one's life, and one would have more control); a decrease in anxiety and depression levels; and decreases in hostility and paranoia.

Wilderness Family Therapy—There is very little in the literature concerning wilderness family therapy. A delphi study of adventure family therapy professionals (Burg 1994) has documented some of the issues, outcomes and directions in this field, of which wilderness family therapy would be a part. The primary benefits to families in adventure family therapy seem to be the development and recognition of family strengths and resources including trust, communication, cohesiveness and fun. Wilderness family therapy is different from other types of wilderness therapy in that there are strong pre-established bonds among family members, a previous history and culture among participants, and increased intensity of interactions. A major need of the field, as indicated in the Burg study, is a decision about which family therapy theories seem to be most effective and appropriate for adventure family therapy, as well as the need for more outcome and process research.

The major study on wilderness family therapy is by Bandoroff and Scherer (1994), who studied 27 families who participated with their at-risk adolescent children in the last four days of a wilderness treatment program. The adolescents had just completed a 21-day wilderness survival expedition, where they were each given the basic necessities (a blanket, knife, one set of clothes, journal and survival rations). The youth had to master a number of primitive living skills (matchless fires) before finishing the course. The last three days of the course were done solo. The wilderness family therapy sessions consisted of the family camping together in a wilderness camping situation, where the youth taught their families some of the wilderness skills they had learned while on their expedition. The program also included family therapy, multiple family therapy, parents solos, negotiation skills and contracting. The research showed an increase in self-concept among adolescents during the expedition, an increase in normal family functioning, a decrease in adolescent rating of delinquency, a decrease in parental-reported problem behavior of the adolescents, and a decrease in parental reported police and court contacts of their adolescent children.

Implications

Implications for Educators

A review and synthesis of the research on the benefits of organized group wilderness experiences revealed four major category of implications for educators and those who sponsor, lead and/or facilitate these types of experiences: skill levels of leaders; the pervasiveness of outcomes; the impact of the group dynamics on benefits; and the role of experiential education in group facilitation.

Intuition tells us that the leader or facilitator of these organized wilderness group experiences can have major influences on the benefits that individuals can realize from participation. These programs operate in a unique situation because of the isolation created by the wilderness environment, the leader is the sole authority and has sole responsibility for all elements of the individual and group processes, 24 hours a day. The leader can have a great deal of influence on whether the individuals and the group realize their and the organization's goals. There has been a long debate in the wilderness leadership field about the necessary qualities and competencies of wilderness group leaders. A recent meta-analysis of nearly 100 wilderness group research studies (Hattie and others 1997) indicates that wilderness program leaders who are trained as teachers or therapists are more effective in creating individual and group growth and goal attainment than those wilderness program leaders who may be highly skilled outdoor adventurer but not professionally-trained teachers or therapists. The research reported in this review indicates that the organized wilderness program field needs to pay more attention to the quality of leadership of wilderness group programs. Researchers also need to pay more attention to how the quality of leadership and different types of leadership influence the benefits attained through wilderness group programs.

The benefits and outcomes of these group programs are deeper and more extensive than the research community's limited ability to document those benefits. These wilderness group programs often have deep, profound and lasting influences on the lives of participants (Hattie and others 1997; Paxton 1998; Pohl 1998). The wilderness research community should treat these programs seriously. The group wilderness programming community must strive to offer high quality programs; and the wilderness management community needs to provide access to wilderness because of the significant benefits these programs provide for their participants.

Roggenbuck and Driver, in another paper in these proceedings emphasize four dimensions of a "lived experience" of wilderness use by individuals. These are anticipation of the experience, on-site elements of the experience while in wilderness, the reflection back on the experience after returning home and the integration of the benefits of the experience into one's everyday life. A possible fifth dimension may well be the group dynamics within these organized wilderness group experiences. The group dynamics, group interaction and group development that happen during group experiences tend to influence most of the potential and documented benefits reported in this paper . The reality is that if the group dynamics work and help precipitate a positive experience, the participants can acquire a number of benefits. If the group dynamics do not work, the benefits may not materialize.

The authors of this review recommend that wilderness group programs be more pro-active in incorporating the experiential education process model into their programs. This review indicated that programs that most successfully realized their stated program goals used a version of the experiential education model. The experiential education model includes the components: authenticity (activities and consequences are related to participants' lives); active learning (participants are physically and mentally engaged in the learning process); drawing on experiences (participants are guided in understanding experiences through reflection);

and, providing opportunities for connecting experience to future opportunity (participants develop skills and knowledge that is useful to them in the future) (Carver 1996; Luckman 1996). This pedagogical approach and sequence of program components helps participants to be better equipped to reflect on their wilderness experience and to incorporate the wilderness program benefits into their everyday personal and work lives.

Implications for Researchers

A number of implications for researchers can be formulated from this review of research literature on organized wilderness group programs and experiences. Some are recommendations for directions of the research in this general topic, and others relate more directly to research design and methods that need to be addressed in the future. More specific directions for future research can be found in a later section of this paper.

Organized wilderness group programs consist of a number of components intended to individually or in combination produce the benefits and outcomes that are stated in the program goals. Most research in this field has focused on the benefits, and very little research has concentrated on understanding the different components that make up the group wilderness experience. There is a need to analyze the program components that make up these programs to determine which program elements are actually creating the benefits and outcomes. Are specific program components crucial to creating benefits, is there a specific combination of components that produce specific benefits, and what is the most effective sequence of program components that results in the desired benefits? Many group wilderness programs are based on the Outward Bound model of program components and sequencing. Researchers need to address whether that is the most effective model. Are there alternative models that are more effective for specific populations or for specific program benefits?

Wilderness group programs have long been criticized as "feel good" experiences that have little significant or lasting influence on the lives of participants. Early research using standardized testing instruments contributed to that criticism because it indicated that gains made during the experience often dissipated after time. These studies indicated participants returned to pre-experience levels shortly after the experience. Critics of wilderness group programs claimed they were simply a nice camping vacation, but had little lasting value for personal or group development. More recent studies, however, and even the re-analysis of some earlier data from studies, are showing that some of these programs and experiences can and do have major life changing influences on participants (Hattie and others 1997). These more recent studies are showing that the benefits gained on these programs can be transferred into the everyday lives of the participants (Paxton 1998; Pohl 1998). Future research in this field needs to address the transference of the benefits of these programs into the work, school and personal lives of the participants. Research should also focus on more than the immediate or the short-term benefits of these programs and instead center on the longer term benefits to the lives of the participants.

Diversity is an issue that is concerned with both the research topics selected and the methods selected. Many of the past studies of organized wilderness groups focused on people who typically comprised a stereotypic Outward Bound program. These participants/research subjects tended to be young adult, male, affluent or from affluent families, and college students. Other research focused on psychiatric and mental health patients, "youth-at-risk," adjudicated youth and other population segments. More recent studies are addressing a broader range of participants, and indications are that this will be the wave of the future. More studies are being reported that now address women, girls, persons of color, corporate executives, persons with physical disabilities, persons with developmental and/or cognitive disabilities, families, youth with problem behaviors, and elderly persons. Diversity in selected methods means that researchers need to pay more attention to those that will accurately measure or more fully describe the benefits which a more diverse population of participants receive from these programs. This means that some of the traditional paper-pencil, psychological testing approaches, or even the mailed questionnaire approach, may not be appropriate for some populations. Some populations cannot fully participate in these data collection methods because of language limitations. Others prefer other methods to share such intimate topics as the benefits or long-term outcomes of a wilderness program. These populations may be best approached using some of the more qualitative research methods, like interviews and journal analysis.

Researchers seeking to better document and describe the benefits and outcomes of organized wilderness group programs need to utilize multi-dimensional research approaches to understand the complex processes and benefits associated with these programs. Scholars need to identify not only the benefits of these experiences, but also how these benefits are created and why they are so important to the lives of participants. Scholars should use not only traditional research methods to document the benefits, but also the more qualitative approaches to understand the nature of the experiences and benefits. There are a number of recent and current studies that are using a multi-dimensional approach, utilizing some of the more qualitative methods to try and understand the why and the how of these group programs. These methods include: in-depth personal interviews of participants during and/or after the wilderness experience (McAvoy and others 1989; Paxton 1998; Pohl 1998); task analysis and single-subject designs (Anderson and others 1997); journal analysis and focus groups (Russell and others 1998); and experience sampling (Anderson and others 1997).

Research on these programs has been criticized for its lack of appropriate testing and assessment tools to document the potential benefits. This was especially the case in some of the past research on therapeutic programs. Many of the psychological testing instruments were simply not appropriate for programs that did not take place in a lab or institutional setting. The research field needs to develop and test new, innovative and appropriate instruments that will accurately measure the changes, outcomes and benefits that can accrue as a result of participation in these wilderness group programs.

Most studies reviewed for this paper have limitations, usually because these types of programs present the researcher with significant challenges in the "control" element of the research design. Our challenge as researchers is to continue to find ways in which to conduct valid and reliable research, and yet not be so intrusive that the research process significantly influences or diminishes the experience of the participant. Wilderness presents the opportunity for major benefits to the participants of these programs. Researchers must realize that the ethics of research always demand that no harm comes to the participant. Harm may include missed opportunities for growth as much as overt damage to an individual. Ethics demand that researchers keep the welfare of the participant foremost in the list of priorities and avoid creating research methods that obstruct the participant's ability to realize the potential benefits of wilderness group experiences.

Implications for Managers

Given the findings described above, there are a number of implications that may be useful for managers. First is the argument of priority. Given the type and level of personal and societal benefits they provide, if wilderness locations are effective in producing positive changes, particularly when they are linked to a properly designed and led program, should education and therapeutic organizations receive preferential treatment over commercial organizations? One could argue that commercial organizations also provide benefits, but programs that are designed to be educational and/or therapeutic clearly produce those types of outcomes more readily than those programs that are primarily recreational.

Second, does wilderness need to be part of the programing requirements? As discussed elsewhere in this paper, the effect of wilderness on outcomes is confounded by a host of other variables. There can be little doubt that, in certain situations and with certain programs, wilderness, particularly officially-designated wilderness areas, may be a necessity. However, for many, if not most, programs and groups, the accomplishment of pre-determined goals may not be a complete necessity.

The final implication is the proverbial problem faced by managers of what takes precedence—beneficial participant outcomes or resource protection. While it is true that groups can use wilderness resources and practice environmentally-sound practices to reduce impacts, it is also true that any use by humans, however well intentioned and practiced, generally leads to impacts of various types. What this paper has demonstrated is that wilderness participation by groups results in a variety of positive outcomes. These outcomes transcend simple recreational values, but they also include personal growth and development and therapeutic aspects. While it is often difficult to partition out what factor creates what outcome, it is clear that these types of programs and experiences result in beneficial and demonstrable individual, group and societal outcomes. Thus, it is no longer the case that precluding use simply precludes some recreation use; the outcomes increasingly are more serious and important.

Directions for Future Research

Perusal of the process and paper provides three items for consideration in ascertaining where and how research should proceed in the investigation of wilderness experiences and groups. First, increased attention should be shown to both secondary as well as primary outcomes. That is, a primary outcome might be self-concept, while a secondary outcome may be environmental awareness or a change in beliefs (Hanna 1995). Much effort is spent on the primary outcomes although it could be argued that the secondary or more hidden outcomes are as important for both the individual and ultimately, society.

Second, as has been stated elsewhere, research on this topic, like many other topics related to natural environments and humans, needs to employ a multi-dimensional approach (Hattie and others 1997; Scherl, 1986). Most studies have not and will not capture the multitude of variables, the complexity of the setting or the interaction within and between the group, among other factors to consider when people and wilderness meet.

The final item from a research perspective, is the issue of recreation vs. education and therapy. As Crisp (1998) suggests, wilderness programs can vary from recreation to enrichment to therapy. While recreation and therapy are self-explanatory, enrichment refers to programs or experiences that are educational or aesthetic in nature and provide the participant with something other than a purely recreational experience. It is our belief that the field has enough research on the recreational aspects of the wilderness trip. Juxtaposed to this position is our belief that research efforts should now focus on the outcomes of enrichment and therapeutic perspectives of wilderness use. We believe that it is in these areas that wilderness can play its most important role in society for the 21st century.

References

Anderson, L., Schleien, S., McAvoy, L., Lais, G., & Seligman, D. 1997. Creating positive change through an integrated outdoor adventure program. Therapeutic Recreation Journal, 31(4). 214-229.

Asher, S., Huffaker, G., & McNally, M. 1994. Therapeutic considerations of wilderness experiences for incest and rape survivors. Women & Therapy. 15(3-4). 161-174.

Bandoroff, S., & Scherer, D. 1994. Wilderness family therapy: An innovative treatment approach for problem youth. Journal of Child and Family Studies, 3(2). 175-191.

Bandura, A. 1977. Self-efficacy: toward a unifying theory of behavioral change. Psychological Review, 84. 191-212.

Baumeister, R.F. 1998. The self. In: D.T. Gilbert, S.T. Fiske, G. Lindzey, eds. The handbook of social psychology. Boston: The McGraw-Hill Companies. 680-740.

Bergon, F. ed. 1980. The wilderness reader. Reno, NV: University of Nevada Press.

Berman, D., & Anton, M. 1988. Wilderness therapy program as an alternative to adolescent psychiatric hospitalization. Residential Treatment for Children and Youth, 5(3). 41-53.

Borstelman, L.J. 1977. Psychological readiness for and change associated with the Outward Bound program. Unpublished paper presented to North Carolina Outward Bound School.

Burg, J. 1994. Exploring adventure family therapy: A modified delphi study. Dissertation Abstracts International. 56(02B). 1148-199.

Carver, R. 1996. Theory for practice: A framework for thinking about experiential education. Journal of Experiential Education. 19 (1): 8-13.

Cooley, R. 1998. Wilderness therapy can help troubled teens. International Journal of Wilderness. 4(3): 18-21.

Crisp, S. 1998. International models of best practice in wilderness and adventure therapy. In Itin, C.M. ed. Exploring the boundaries of adventure therapy: International perspectives. Pp 56-74. Boulder, CO: Association for Experiential Education.

Curry, N.E., Johnson, C.N. 1990. Beyond self-esteem: developing a geniune sense of human value. (Research Monograph Volume 4). Washington, D.C.: The National Association for the Education of Youth.

Davis-Berman, J., Berman, D.S., & Capone, L. 1994. Therapeutic wilderness programs: a national survey. Journal of Experiential Education, 17(2). 49-53.

Driver, B.L., Easley, A.T., Passineau, J.F. 1990. Introductory comments on the benefits of wilderness. In A.T. Easley, J.F. Passineau, B.L. Driver, comp. The use of wilderness for personal growth, therapy, and education. Gen. Tech. RM-193. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 1-10

Driver, B.L., Peterson, G.L. 1987. Benefits of outdoor recreation: an integrating overview. In: A literature review - President's Commission on Americans Outdoors. Washington, D.C.: Government Printing Office. 1-10.

Driver, B.L., Nash, R. and Haas, G. 1987. Wilderness benefits: a state-of-knowledge review. In Lucas. R., ed. Proceedings - national wilderness research conference: issues, state-of-knowledge, future directions. 1985 July 23-26; Fort Collins, CO. Gen. Tech. Rep. INT-220. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 294-319.

Easley, A.T., Passineau, J.F., Driver, B.L., comp. 1990. The use of wilderness for personal growth, therapy, and education. Gen. Tech. RM-193. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 197 pages.

Eggleston, E. 1998. Reflections on wilderness therapy. In Itin, C.M. ed. Exploring the boundaries of adventure therapy: International perspectives. pp 265-285. Boulder, CO: Association for Experiential Education.

Elrod, P., & Minor, K. 1992. Second wave evaluation of a multifaceted intervention for juvenile court probationers. International Journal of Offender Therapy and Comparative Criminology, 36(3). 247-262.

Ewert, A.W. 1982. A study of the effects of participation in an Outward Bound short course upon the reported self-concepts of selected participants. Unpublished Ph.D. dissertation, University of Oregon.

Ewert, A., Baker, D. 1998. Standing up for where you sit: the relationship between environmental position and disciplinary background. Seventh International Symposium on Society and Resource Management, University of Missouri-Columbia, Columbia, MO, May 27-31, 1998.

Ewert, A. W., Heywood, J. 1991. Group development in the natural environment: expectations, outcomes, and techniques. Environment and Behavior, 23, 592-615.

Ewert, A.W., Hollenhorst, S.J. 1990. Risking it on wildlands: the evolution of adventure recreation. Journal of Environmental Education, 21(3): 29-36.

Fredrickson, L. & Anderson, D. (1999) A qualitative exploration of the wilderness experience as a source of spiritual inspiration. Journal of Environmental Psychology. 19:21-39.

Fried, K. 1994. The impact of a vigorous physical and emotionally demanding social experience on modifying adolescent self-concept. Dissertation Abstracts International. 54(11-B).

Friese, G. T.1996. A typology and survey of wilderness experience programs nationwide. Unpublished master's thesis, University of Idaho, Moscow.

Friese, G. Hendee, J. C., & Kinziger, M. 1998. The wilderness experience program in the United States: characteristics and dynamics. Journal of Experiential Education, 21(1): 40-45.

Friese, G.T., Pittman, J.T., Hendee, J.C. 1995. Studies of the use of wilderness for personal growth, therapy, education, and leadership development: an annotation and evaluation. Moscow, ID: University of Idaho Wilderness Research Center.

Gager, R. 1977. Experiential learning process flow. Voyageur Reports. Boulder, CO: Journal of Experiential Education, 1, 4-5.

Gager, D. 1996. Agency policies and wilderness managers attitudes towards wilderness experience programs. Unpublished master's thesis. University of Idaho.

Gager, D., Hendee, J., Kinzinger, M., Krumpe, E. 1998. What managers are saying and doing about Wilderness Experience Programs. Journal of Forestry, 96(8): 33-37.

Gass, M. ed.1993. Adventure therapy: Therapeutic applications of adventure programming. Dubuque, IA: Kendall/Hunt.

Gillett, D.P., Thomas, G.P. Skok, R.L. McLaughlin, T.F. 1991. The effects of wilderness camping and hiking. Journal of Environmental Education, 21, 33-44.

Gillis, H., & Simpson, C. 1991. Project Choices: Adventure-based residential drug treatment for court-referred youth. Addictions and Offender Counseling, 12(1). 12-27.

Gillis, H.L. 1992. Therapeutic uses of adventure-challenge-outdoor-wilderness: Theory and research. Coalition for Education in the Outdoors: First Research Symposium Proceedings, Jan17-19, 1992, pp.35-47. Cortland, NY: Coalition for Education in the Outdoors, State University of New York College at Cortland.

Gillis, H., & Thomsen, D. 1996. A research update of adventure therapy (1992-1995): Challenge activities and ropes courses, wilderness expeditions, and residential camping programs. Coalition for Education in the Outdoors: Third Research Symposium Proceedings, Jan 12-14, 1996, pp. 77-90. Cortland, NY: Coalition for Education in the Outdoors, State University of New York College at Cortland.

Graham, J. 1997. Outdoor leadership: technique, common sense and self-confidence. Seattle, WA: The Mountaineers.

Hanna, G. 1995. Wilderness-related environmental outcomes of adventure and ecology education programming. Journal of Environmental Education, 27, 21-32.

Hattie, J., Marsh, H.W., Neill, J.T. & Richards, G.E. 1997. Adventure education and Outward Bound: Out-of-class experiences that make a lasting difference. Review of Educational Research, 67(1): 43-87.

Henderson, K.A. 1996. Women and the outdoors: Toward spiritual empowerment. In Warren, K. ed. Women's voices in experiential education (pp. 193-202). Dubuque, IO: Kendall/Hunt Publishing.

Herbert, J. 1998. Therapeutic effects of participating in an adventure therapy program. Proceedings of the 1998 American Sociological Society Conference, 41(3). 201-216.

Hornibrook, T., Brinkert, E., Parry, D., Seimens, R., Mitten, D. & Priest, S. 1997. The benefits and motivations of all women outdoor programs. Journal of Experiential Education, 20 (3):152-158.

Itin, C.M. ed. 1998. Exploring the boundaries of adventure therapy: International perspectives. Boulder, CO: Association for Experiential Education.

Jenseth, R., Lotto, E.E. 1996. Constructing nature: readings from the American experience. Upper Saddle River, NJ: Prentice-Hall, Inc.

Jones, J.E., Bearley, W.L. 1986. Group development assessment questionnaire. Pittsburgh, PA: Organizational Design and Development, Inc.

Kaplan, S., Talbot, J.F. 1983. Psychological benefits of a wilderness experience. In I. Altman and J.F. Wohlwill, eds, Human behavior and environment: behavior and the natural environment. New York: Plenum. (Vol. 6, pp. 163-203).

Kellert, S. 1999. A national study of wilderness experience. In: R. Wizansky, S. Reed, New study demonstrates outdoor experience may prove life changing to adolescents, help solve education woes, The Outdoor Network, Vol. IX, Issue 4, 1, 27.

Kelley, M. P., Coursey, R. D., & Selby, P. M. 1997. Therapeutic adventures outdoors: A demonstration of benefits for people with mental illness. Psychiatric Rehabilitation Journal, 20(4). 61-73.

Lee, M.E., Driver, B.L. 1999. Benefits-based management: a new paradigm for managing amenity resources. In: J. Aley, W.R. Burch, B. Conover, and D. Field, eds. Ecosystem management: adaptive strategies for natural resources organizations in the 21st century. Philadelphia: Taylor and Francis. 143-154.

Leon, G.R., Kanfer, R., Hoffman, R.G., Dupre, L. 1994. Group processes and task effectiveness in a Soviet-American expedition team. Environment and Behavior, 26, 149-165.

Luckner, J.L. 1989. Effects of participation in an outdoor adventure education course on the self-concept of hearing-impaired individuals. American Annals of the Deaf, 134(1): 45-49.
Luckman, C. 1996. Defining experiential education. Journal of Experiential Education. 19 (1): 6-7.
Lucas, R.C. 1987. Perspectives on the history of wilderness research. In: Lucas, R.C. 1987. Proceedings - national wilderness research conference: issues, state-of-knowledge, future directions. 1985 July 23-26; Fort Collins, CO. Gen. Tech. Rep. INT-220. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 15-28.
Marsh, H.W., Richards, G.E., Barnes, J. 1986. Multidimensional self-concepts: A long-term follow-up of the effect of participation in an Outward Bound Program. Personality and Social Psychology Bulletin, 12, 475-492.
McAvoy, L., Lais, G., Anderson, L. & Schleien, S. 1995. Wilderness and person with disabilities: A review of research and policy directions. Trends, 32(1): 33-37, 48.
McAvoy, L., Schatz, C., Stutz, M., Schleien, S., & Lais, G. 1989. Integrated wilderness adventure: effects on personal and lifestyle traits of persons with and without disabilities. Therapeutic Recreation Journal, 23(3). 50-64.
McCord, D. 1995. Toward a typology of wilderness-based residential treatment program participants. Residential Treatment for Children and Youth, 12(4). 51-60.
Minor, K., & Elrod, P. 1994. The effects of a probation intervention on juvenile offenders' self-concepts, loci of control, and perception of juvenile justice. Youth and Society, 25(4). 490-511.
Mitten, D. 1994. Ethical considerations in adventure therapy: A feminist critique. Women & Therapy. 15(3/4):55-84.
Mossman, E. An evaluation of the outdoor challenge program (OACP) at Rolleston Prison. In Itin, C.M. ed. Exploring the boundaries of adventure therapy: International perspectives. pp.293-304. Boulder, CO: Association for Experiential Education.
Nash, R. 1982. Wilderness and the American mind. New Haven, CT: Yale University Press.
Neill, J.T. 1997. Gender: how does it effect the outdoor education experience? Paper presented to the 10th National Outdoor Education Conference, Sydney, Australia, January 20-24, 1997.
Neill, J. & Heubeck, B. 1998. Adolescent coping styles and outdoor education. In Itin, C.M. ed. Exploring the boundaries of adventure therapy: International perspectives. pp. 227-243 . Boulder, CO: Association for Experiential Education.
Oakes, P.J., Haslam, S.A., Morrison, B., Grace, D. 1995. Becoming an in-group: reexamining the impact of familiarity on perceptions of group homogeneity. Social Psychology Quarterly, 58, 52-61.
Pawlowski, M., Holme, G., & Hafner, R. 1993. Wilderness therapy for psychiatric disorder. Mental Health in Australia, 5(1). 8-14.
Paxton, T. 1998. Self-efficacy and outdoor adventure programs: A quantitative and qualitative analysis. Unpublished doctoral thesis. Minneapolis, MN: University of Minnesota.
Payne, D.G. 1999. "Talking freely around the campfire": the influence of nature writing on American environmental policy. Society and Natural Resources, 12(1): 39-48.
Pohl, S. 1998. Women, wilderness and everyday life: An examination of the connection between wilderness recreation and women's liberation. Unpublished masters thesis. Missoula, MT: University of Montana.
Powch, I. 1994. Wilderness therapy: What makes it empowering for women? Women & Therapy, 15(3-4). 11-27.
Propst, D.B., Koesler, R.A. 1998. Bandura goes outdoors: role of self-efficacy in the outdoor leadership development process. Leisure Sciences, 20, 319-344.
Robb, G. M. & Ewert, A. 1987. Risk recreation and persons with disabilities. Therapeutic Recreation Journal, 21(1). 58-69.
Roberts, A., & Camasso, M. 1991. Juvenile offender treatment programs and cost benefit. Juvenile and Family Court Journal, 42(1). 37-45.
Robinson, D. W. 1991. Adventure recreation programming for the developmentally challenged: a pilot study on affective change. In: Bell, F. I. & Van Gyn, G. H. eds. Proceedings for the 10th Commonwealth and International Scientific Congress: Access to Active Living. 498-502. Victoria, B. C.: University of Victoria.
Roggenbuck, J.W., Lucas, R.C. 1987. Wilderness use and user characteristics: a state-of-knowledge review. In Lucas. R., ed. Proceedings - national wilderness research conference: issues, state-of-knowledge, future directions. 1985 July 23-26; Fort Collins, CO. Gen. Tech. Rep. INT-220. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 204-245.
Rose, S., & Massey, P. 1993. Adventurous outdoor activities: An investigation into the benefits of adventure for seven people with severe learning difficulties. Mental Handicap Research, 6(4). 287-302.
Russell, K.C. & Hendee, J.C. 1999. Wilderness therapy as an intervention and treatment for adolescents with behavioral problems. . In, Watson, A.E., Aplet, G. ed. Personal, societal and ecological values of wilderness: Sixth world wilderness congress proceedings on research, management and allocation, Vol. II, Proc. RMRS-P-000. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.
Russell, K., Hendeee, J.C., & Cooke, S. 1998. Social and economic benefits of a U.S. wilderness experience program for youth-at-risk in the federal Job Corps. International Journal of Wilderness. 4(3): 32-38.
Sachs, J.J., Miller, S.R. 1992. The impact of a wilderness experience on the social interactions and social expectations of behaviorally disordered adolescents. Behavioral Disorders, 17, 89-98.
Sale, P. 1993. Ego and self-concept development among juvenile delinquent participants in adventure-based programming. Dissertation Abstracts International, 53 (7-A). 2253.
Scherl, L. 1986. Self in wilderness: is personal control a viable notion for understanding individual-wilderness interaction? Paper presented at the 15th Annual Meeting of Australian Social Psychologists, Townsville.
Scherl, L. 1988. Constructions of a wilderness experience: Using the repertory grid technique in the natural setting. Australian Psychologist, 23(2). 225-242.
Simpson, S. 1985. Short-term wilderness experiences and environmental ethics. Journal of Experiential Education, 8, 25-28.
Stankey, G.H., R. Schreyer. 1987. Attitudes toward wilderness and factors affecting visitor behavior: a state-of-knowledge review. In Lucas. R., ed. Proceedings - national wilderness research conference: issues, state-of-knowledge, future directions. 1985 July 23-26; Fort Collins, CO. Gen. Tech. Rep. INT-220. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 246-293.
Sveen, R., & Denholm, C. 1997. Testing the theoretical fit of an abseiling harness: A study of an Australian primary and secondary prevention program. Journal of Primary Prevention, 18(2). 213-225.
Traynelis-Yurek, E., & Giacobbe, G. 1988. Length of stay and recidivism after a quality treatment program. International Journal of Adolescence and Youth, 1(3). 257-267.
Walsh, V., Golins, G. 1975. The exploration of the Outward Bound process. Denver: Colorado Outward Bound School.
Wichmann, T. 1991. Interpersonal problem solving and asocial behavior in a therapeutic wilderness program. Dissertation Abstracts International, 52(5-A). 1697-1698.
Wood, J. Lugg, D., Hysong, S.J. Harm, D.L. 1999. Psychological changes in hundred-day remote Antarctic field groups. Environment and Behavior, 31, 299-337.

Global Change in Wilderness Areas: Disentangling Natural and Anthropogenic Changes

Lisa J. Graumlich

Abstract—Human impacts on the Earth's ecosystems are globally pervasive. Wilderness areas, although largely protected from direct human impact at local scales, nevertheless are subject to global changes in atmospheric composition, climate and biodiversity. Research in wilderness areas plays a critical role in disentangling natural and anthropogenic changes in ecosystems by providing a network of sites where local impacts are minimized relative to adjacent, more intensely managed areas. Three case studies are discussed to illustrate the role of wilderness areas in global change research and, specifically, how paleoecological data provide baseline documentation of variability in climate and ecosystem processes.

The motivation to designate wilderness areas as research sites stems from a recognition that human influences on the Earth's ecosystems are multiple and pervasive. As such, wilderness areas, and more generally biosphere reserves, are traditionally thought of as parcels of land protected from human influence. A theme that strongly emerges from contributions to the Wilderness Science in a Time of Change Conference is that wilderness boundaries are porous with respect to human impacts, especially those impacts commonly referred to as global change. In this paper, I explore opportunities for research in wilderness areas engendered by increasingly complex relationships between human agency and the environment.

In considering the current and potential impacts of global change on wilderness areas, it is useful to define global change broadly enough to encompass both systemic and cumulative changes (Turner and others 1990; fig. 1). Systemic impacts on the Earth, such as increasing trace gases, are global because the atmosphere dynamically mixes carbon dioxide and other gases, and their impacts on ecosystems and the climate system are registered over the entire Earth. Cumulative impacts on the Earth, such as land-use change, changes in biodiversity and alteration of the nitrogen cycle, are increasingly global in scale due to the accretion of local and regional changes (Vitousek and others 1997; Vitousek this volume). Under this perspective of global change, wilderness boundaries offer little or no protection from either systemic global changes, such as increasing carbon dioxide and associated changes in climate, or cumulative global changes, such as changes in fire regime or invasive species.

Given that human impacts on ecosystems increasingly extend to areas previously considered pristine, what role can wilderness, or more generally protected areas, play in scientific research? The answer lies in two veins of inquiry that have become increasingly important in the attempt to disentangle natural and anthropogenic environmental changes. First, research based in wilderness and other less managed areas is critical to detecting the impact of climate change because it uses settings with minimal human influence. In essence, protected areas can be thought of as the "canaries in the coal mine," that is, sites where impacts may initially be manifest. Second, research in protected areas offers a powerful approach to the problem of attributing change to human vs. natural causes. Protected areas, in combination with adjacent, more intensely managed areas, offer settings where human alteration of ecosystems processes can be observed and, in many cases, quantified (Vitousek this volume). In this context, paleoecologists have vigorously exploited wilderness areas as sites for research aimed at detecting global changes as well as attributing changes to appropriate drivers. As such, wilderness areas are rich repositories of paleoclimate and paleoecological data (for example, tree rings, sediment cores, macrofossil deposits). The significance of these natural archives is that they allow us to study climate-ecosystem interactions under conditions that are novel compared to present conditions.

In this paper, I argue for the value of wilderness areas as sites for research by reviewing three case studies in which

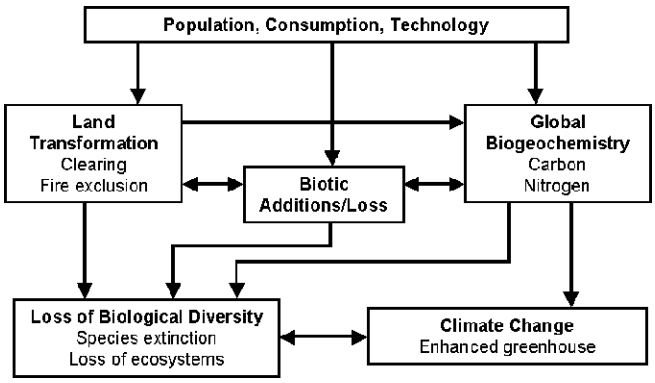

Figure 1—A conceptual model illustrating humanity's direct and indirect effects on the Earth system (modified from Vitousek and others 1997).

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paleoenvironmental data from large natural areas enhanced our understanding of the current and potential impact of global environmental change on climate—ecosystem interactions. The case studies were chosen, in part, for their ability to describe dynamics over the past 1,000+ years. The last millennium encompasses variability in climate exceeding that observed during the 20th century (Graumlich 1993; Hughes and Diaz 1994). Well-documented anomalies in past climate present us with an opportunity to study climate—ecosystem interactions falling outside the bounds of multi-year field observations, or even historical records spanning the current century (Graumlich and Brubaker 1995). Finally, the case studies were chosen to illustrate the range of scales at which paleoenvironmental data can contribute to our understanding of natural variability and process. The case studies and associated scales of research are:

- A landscape-scale study of upper treeline in the southern Sierra Nevada that documents dramatic ecotonal changes over 3,000+ years (Lloyd and Graumlich 1997)
- A regionally scaled study of climate, fire and forest interactions in the American Southwest (Swetnam and Betancourt 1998)
- A globally scaled study of the nature of climate variability and its causes (Mann and others 1998; Mann and others 1999)

Landscape-Scale Research: Multi-millennial Records of Climate Variation and Treeline Response in the Sierra Nevada

Paleoecological records from protected areas have been critical to development of our current understanding of how climatic variability affects forests, especially forests growing at or near their temperature limits. In particular, studies of alpine treeline have indicated that it is a sensitive ecotone, responding to multi-decadal temperature trends (Graumlich 1994; Körner 1998). As such, when seedlings established above current treeline during the past several decades at mid- and high latitude sites, some interpreted it as an indicator of global warming (Rochefort and others 1994). If we are to use upper treeline as a bellwether of global climate change, we must understand the processes that control its variability. Defining the variability of relevant population processes requires observations that span several decades, if not centuries, as a baseline.

Dendroecological studies of treeline have provided context for assessing current observations of directional change at this ecotone. The case study below describes work I did with Andrea Lloyd in the southern Sierra Nevada, where we have taken advantage of relatively pristine study sites to examine population processes influenced by multi-decadal changes in climate (Lloyd and Graumlich 1997). In particular, we investigated two questions: 1) How has the abundance of trees beyond the current distributional limits of subalpine forests changed over the past few millennia? 2) How do changes in the position and population structure of subalpine forests relate to climate variability?

Dead trees at and above treeline in the eastern Sierra Nevada of California are preserved in situ for millennia. Such subfossil wood testifies to the dynamic behavior of treeline in the late Holocene. Recent seedling establishment above current treeline suggests that forest structure and composition changes may be accelerating and continue in the future. The combination of recent ecotone change and highly resolved paleoecological records presented an opportunity to place vegetation dynamics of the past decade into a broader context to determine if current dynamics had analogs in the past and, if so, to attribute past changes to appropriate driving factors. More specifically, we combined investigations of climatic history from tree rings and other proxy climatic sources with studies of foxtail pine (*Pinus balfouriana*) treeline dynamics on the eastern crest of the Sierra Nevada in Sequoia and Kings Canyon National Parks.

The climate history of the Sierra Nevada biogeographic region is well known from a wealth of independent paleoclimatic data. Tree-ring data from subalpine conifers and giant sequoia (*Sequoia sempervirens*) in the Sierra Nevada and bristlecone pine (*Pinus longaeva*) in the adjacent White Mountains provide well-validated inferences about seasonal climatic variation (Graumlich 1993; Hughes and Brown 1992; Hughes and Graumlich 1996). The summer temperature reconstruction shows fluctuations on centennial and longer time scales, including a period with temperatures exceeding late 20th century values from ca. AD 1100 to 1375, corresponding to the Medieval Warm Period identified in other proxy data sources, and a period of cold temperatures from ca. 1450 to 1850, corresponding to the documented Little Ice Age. Reconstructed precipitation variation is dominated by shorter period, decadal-scale oscillations punctuated by very severe single-year drought approximately two to three times per century. A surprising feature of the records is the documentation of multi-decadal droughts (AD 1050-1100 and AD 1200-1350) of much greater severity and length than the drought experienced by California from 1928-1934. These droughts are corroborated by evidence from Mono Lake, located on the east side of the Sierra Nevada (Stine 1994). Tree stump remains were found in place when levels of Mono Lake were artificially lowered over the past several decades. The stumps offer firm evidence that water supplies originating in the Sierra Nevada were reduced to 40% of the 20th century average during long periods in the past.

Treeline dynamics for the past 3,500 years were reconstructed from a tree-ring analysis of subfossil wood at and above current treeline (Lloyd and Graumlich 1997). Treeline elevation in the foxtail pine forests is between 3,300 and 3,500 m in a climate currently characterized as both cold and dry. Because foxtail pine does not adopt a krummholz growth form characteristic of many treeline species, treeline is a relatively abrupt boundary (fig. 2). We selected five study sites at which to reconstruct past changes in tree abundance and treeline position: three sites adjacent to and above current treeline and two sites where changes in treeline were expressed along gradients related to aspect. At each 1-4 ha site, we cored and mapped all subfossil wood. The vast majority of the dead wood could be dated such that we could determine a date of establishment of the adult tree (pith date) and the death date of the tree (outer ring data with correction for sapwood loss).

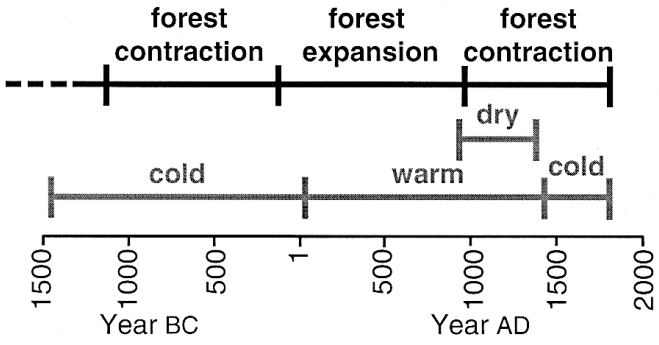

Figure 2—History of abundance of foxtail pine populations at treeline in the eastern Sierra Nevada of California in comparison to past climatic variation over the past 3,500 years. Treeline data are from dates of recruitment and mortality of adult trees at five sites in the region (Lloyd and Graumlich 1997). Climate inferences are from tree ring and geomorphic records (Graumlich 1993; Hughes and Graumlich 1996; Stine 1994).

Our results show that the abundance of trees above treeline changed over the past several millennia in concert with changes in climate (fig. 2). A relatively dense forest grew above current treeline from the beginning of our records to around 100 BC and again from AD 400 to 1000, when temperatures were warm. Abundance of trees and elevation of treeline declined very rapidly from AD 1000 to 1400, the period of severe, multi-decadal droughts. Treeline declined more slowly from AD 1500 to 1900 under the cool temperatures of the Little Ice Age, reaching current elevations around AD 1900. These results indicate that while temperature is an important control on treeline dynamics, the influence of temperature can be modified by drought. In fact, drought can reverse the expected relationship between warm temperatures and increasing populations at treeline, as seen in the period AD 1000 to 1400.

The record of foxtail pine treeline dynamics speaks to the question of whether we are currently witnessing human impacts on climate—vegetation systems. Results from other paleoclimatic studies are similar, indicating a high degree of climatic variability in the past, especially at multi-decadal to multi-century time scales. The treeline results, while only for a single locality, strongly indicate that treeline response to 20th century warming, in the form of seedling establishment above treeline, does not yet exceed changes observed in the past 1,000 years. Thus, the movement of this ecotone does not, at this point, offer evidence of unprecedented change that can be attributed to human activity.

Regional-Scale Research: Climate, Fire, and Forests in the American Southwest

Most studies of disturbance—ecosystem interactions have emphasized local processes and short-time scales. Such research typically focuses on the role of disturbance in creating heterogeneity, specifically patches of different age and/or composition within a landscape. A recent compilation and synthesis of a decade of research on fire ecology in the American Southwest by Swetnam and Betancourt (1998) offers an important counter to previous studies of disturbance by demonstrating how climate synchronizes fires at regional scales. Regionally scaled fires reset demographic clocks over wide areas, thereby creating similarities in age structures between fire-prone landscapes within a region. The work of Swetnam and Betancourt thus makes an ideal case study demonstrating that research conducted at multiple wilderness sites brings new understanding. In describing their results, I emphasize two innovations in their work. First, an accurate and precise chronology of disturbance events could be documented because low-intensity fires in the Southwest leave a legacy in the form of fire scars that can be dated to the calendar year. Second, a regional approach to the question of climate-fire relationships was feasible because of the existence of a network of wilderness areas and other reserves managed by federal and state agencies that requested and, in many cases, supported the reconstruction of fire history.

Dating of wildfire events that occurred during the past several hundred to several thousand years is possible because low-intensity surface fires are sufficiently hot to damage to the cambium and outermost xylem cells of a tree but not to kill the tree. The resulting fire scars, when magnified in cross-section, show a heat-caused lesion in the xylem tissue. Using techniques of dendrochronology, the scar can be assigned to an exact calendar year and, in many cases, can be linked to a specific season of the year (Fritts and Swetnam 1989). When multiple synchronous fire scar dates are established for numbers of trees at a site, the resulting fire scar chronology is interpreted as a record of wildfires at that site. Such fire scar chronologies have been important in providing guidance to land managers for the frequency and scale at which to reintroduce fire into areas where fire exclusion during the 20th century produced undesired changes in forest structure or composition (for example, Swetnam 1993).

Because the fire scar chronologies for each site are absolutely dated, they can be aggregated to form a regional composite chronology. The most comprehensive composite fire-scar record to date is for the American Southwest and consists of 63 separate fire scar chronologies from 25 different mountain ranges (Swetnam and Betancourt 1998). Each fire-scar chronology within the composite is based on 10 or more trees per stand where stands ranged in size from 10 to 100 ha within ponderosa pine (*Pinus ponderosa*) or mixed conifer woodlands.

The composite fire scar record for the American Southwest indicates that regionally synchronous fires recurred regularly during the period 1700 to 1900 (fig. 3; Swetnam and Betancourt 1998). At individual sites, fires occurred approximately every 7.5 years. At this rate, regionally synchronous fires (defined as fires occurring in one-third of all sites in a given year) would occur by chance alone once every 35,000 years. Instead, the composite record shows regionally synchronous fires occurred 15 times in the 201-year period. Of particular note is the record for 1748, when 41 out of 63 sites experienced a fire. The probability of the 1748 event occurring by chance is one in billions. Swetnam and Betancourt argue that the synchronization of fires at the regional scale must reflect regional to subcontinental drought for one or more seasons. To support this claim, they note the strong correlation between an independent record of Palmer

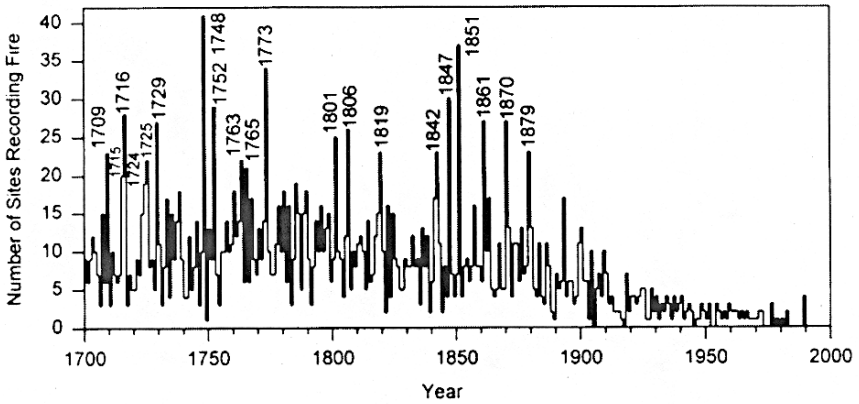

Figure 3—History of fires affecting large portions of the ponderosa pine and mixed conifer forests of the American Southwest as inferred from a network of fire scar records (modified from Swetnam and Betancourt 1998). Years marked with calendar date represent events in which at least one third of sites recorded a fire.

Drought Severity Index (PDSI) and the number of large fires (fig. 4). Drought and fire are, in turn, strongly associated with decadal-scale shifts in the El Niño—Southern Oscillation (ENSO). In particular, high amplitude and rapid shifts between ENSO modes (1740-1780; 1830-1860) are associated with shifts from extreme wet to extreme dry years. The combination of wet anomalies, which induce higher than normal fine-fuel production, followed by dry anomalies is the most important factor for entraining fire occurrence across the region.

The results of Swetnam and Betancourt underscore the importance of assessing ecological patterns and processes at appropriate scales. Their discovery of the role of climatic variation, especially ENSO fluctuations, in synchronizing wildfire across the American Southwest was based on a data set of sufficient size and length of record to uncover the phenomena. Their results give added meaning to the characterization of ecosystems as historically contingent systems, whose structure and dynamics reflect the legacy of the past.

Global-Scale Research: A 1,000-Year Record of Northern Hemisphere Temperature Sheds Light on Recent Anthropogenic Impacts

Arguably, one of the most important scientific questions of the turn of the millennium is deceptively simple: Has human activity changed the Earth's climate? Detecting the impact of increased greenhouse gases on the climate system has remained a vexing problem for the scientific community because the climate system varies naturally on time scales of seasons to millennia. Hence, the challenge in detecting human impact lies in disentangling the effects of increasing greenhouse gases during the 20th century from other factors that cause long-term trends in global climate (such as, variation in solar output and volcanic dust injected into the atmosphere). Instrumental weather data, which extend back approximately 100 years in most parts of the world, are

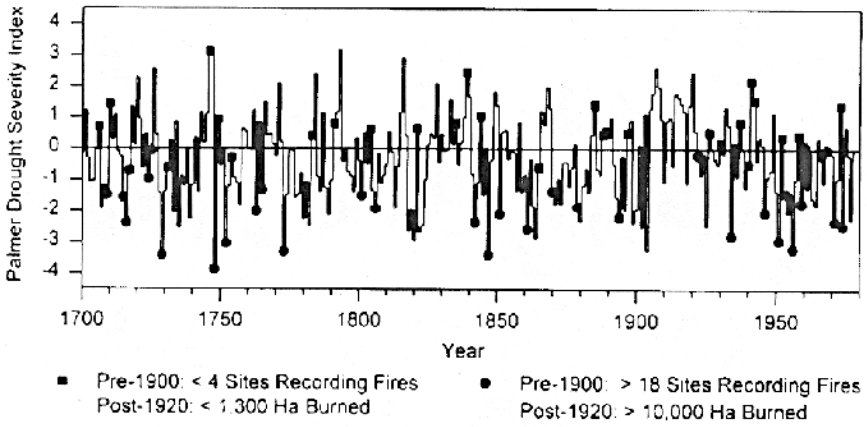

Figure 4—Severe droughts, as reflected in low values of the Palmer Drought Severity Index, synchronize fires in the American Southwest (modified from Swetnam and Betancourt 1998). Conversely, wet years are characterized by a small number of fires with minimal area affected.

inadequate to account for the nature and impact of these other climate change factors. Without temperature records that extend back hundred of years, we cannot determine whether the record high temperatures observed during the 1990s represent greenhouse gas effects or are simply an expression of natural climatic variability.

Mann and others (1998, 1999) recently published a 1,000-year long record of Northern Hemisphere temperature that provides the first strong evidence that 20th century temperature trends in the northern hemisphere exceed those that would be expected from natural variability alone. These new results represent a synthesis of a global network of hundreds of proxy climate records derived from tree rings, glacial ice and lake and ocean sediments, the vast majority of which were collected in wilderness and other protected areas where such climatic proxy data are preserved. Mann and collaborators validated their temperature inferences by demonstrating that the proxy temperature observations are strongly correlated with observational data during the 20th century.

Prior to the 20th century, the 1,000-year record shows slow oscillations of warm and cool temperatures superimposed on a 900-year cooling trend of approximately 1°C (Fig. 5). Comparison of these oscillations with patterns of solar variability and volcanic dust in the atmosphere strongly indicates that these two factors combined to produce the long-term cooling trend, as well as the shorter-term fluctuations in temperature before 1900. The 20th century, in contrast, is dominated by an abrupt increase of approximately 0.5°C. The remarkable nature of recent temperature trends in clear: The decade of the 1990s is the warmest of the last millennium and 1998 is the warmest year observed in the full 1000-year record. The 20th century temperature trend mirrors the rate of accumulation of greenhouse gases. There is no correspondence between the 20th century temperature trends and other possible natural forcing factors such as solar variability. In sum, the 1,000-year Northern Hemisphere temperature reconstruction is the first strong indication that we are now entering a period of Earth's history when human imprint on climate can be detected. This finding adds urgency to the call for including potential climate change scenarios into planning for the management of wilderness areas.

Conclusions

The studies discussed above echo common themes concerning the modern role of wilderness and other protected areas as sites of scientific inquiry. In all cases, opportunities created by the presence of natural areas amid more heavily managed lands allow us to more fully characterize the imprint of human activity on natural ecosystems. Further, when we exploit paleoenvironmental archives derived from these study sites, we define the background variability of the processes that shape ecosystems. Understanding the nature of this variability, both in terms of its causes and its consequences, is increasingly recognized as a key to sound ecosystem management (Morgan and others 1994). Finally, we are increasingly challenged to understand the relationship between changes observed on a given landscape in the context of regional and global trajectories. This task requires the continued development of networks of wilderness and large natural areas to facilitate cross-site comparisons and cross-scale analyses necessary to elucidate the complex interactions between global changes and local response.

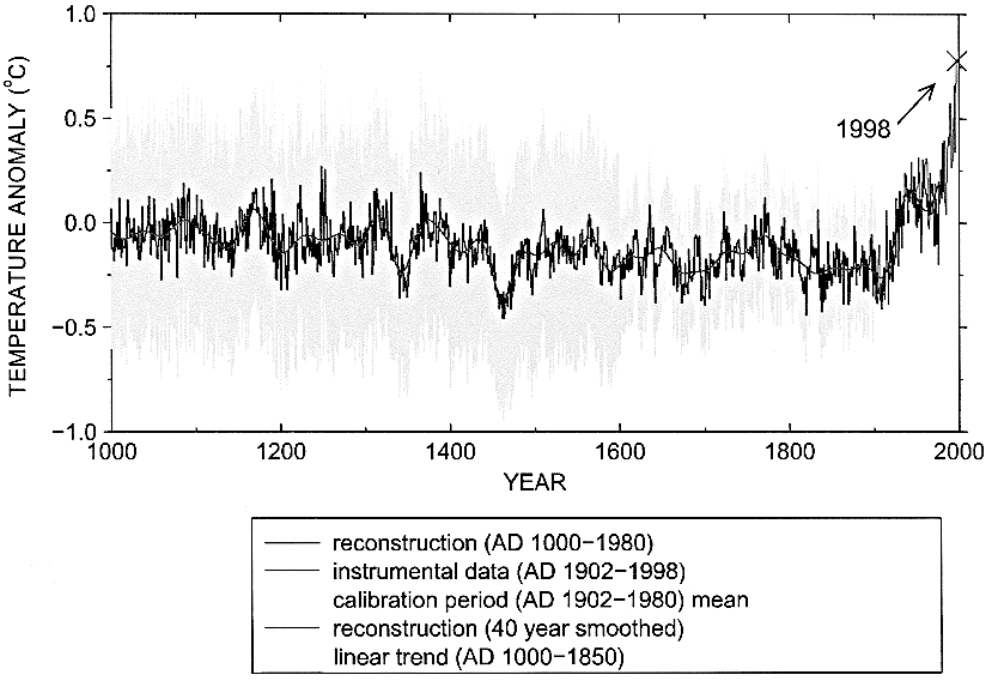

Figure 5—A 1,000-year record of Northern Hemisphere annual temperature inferred from tree rings, glacial ice, corals, and historical records (modified from Mann and others 1999).

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References

Fritts, H. C. and Swetnam, T. W. 1989. Dendroecology: a tool for evaluating variations in past and present forest environments. Advances in Ecological Research 19:111-188

Graumlich, L.J. 1993. A 1000-year record of temperature and precipitation in the Sierra Nevada. Quaternary Research 39, 249-255.

Graumlich, L.J. 1994. Long-term vegetation change in mountain environments: Paleoecological insights into modern vegetation dynamics. In *Mountain Environments in Changing Climates*, M. Beniston, ed., Routledge, London, pp. 167-179.

Graumlich, L.J. and L.B. Brubaker. 1995. Long-term records of growth and distribution of conifers: Integration of Paleoecology and Physiological Ecology. In *Ecophysiology of Coniferous Forests*, W.K. Smith and T.M. Hinckley, eds., Academic Press, New York, pp. 37-62.

Hughes, M. K. and Diaz, H, F. 1994. The Medieval Warm Period. Dordrecht: Kluwer Academic Publishers. 342 p.

Hughes, M.K. and L.J. Graumlich. 1996. Multimillennial dendroclimatic records from the western United States. In Climatic Variations and Forcing Mechanisms of the last 2000 Years, R.S. Bradley, P.D. Jones, and J. Jouzel. NATO Advanced Studies Workshop Series. Springer-Verlag.

Hughes, M.K. and P.M. Brown. 1992. Drought frequency in central California since 101 BC recorded in giant sequoia tree rings. Climate Dynamics 6, 161-167.

Körner, Ch. 1998. A reassessment of high elevation treeline positions and their explations. Oecologia 115: 445-459.

Lloyd, A.H. and L.J. Graumlich. 1997. Holocene dynamics of treeline forests in the Sierra Nevada. *Ecology* 78, 1199-1210.

Mann, M.. E., Bradley, R. S., and M. K. Hughes. 1998. Global-scale temperature patterns and climate forcing over the past six centuries. Nature 392: 779-787.

Mann, M. E., Bradley, R. S., and M. K. Hughes. 1999. Northern Hemisphere temperatures during the past millennium: inferences, uncertainties, and limitations. Geophysical Research Letters 26: 759-762.

Morgan, P., Aplet, G. H., Haufer, J. B., Humphries, H. C., Moore, M. M., and Wilson, W. D. 1994. Historical range of variability: a useful tool for evaluating ecosystem change. Journal of Sustainable Forestry 2:87-111.

Rochefort, R. M., Little, R. L., Woodward, A., Peterson, D.L. 1994. Changes in sub-alpine tree distribution in western North America: a review of climatic and other causal factors. Holocene 4, 89-100.

Stine, S. 1994. Extreme and persistent drought in California and Patagonia during mediaeval time. Nature 369: 546-549.

Swetnam, T. W. 1993. Fire history and climate change in giant sequoia groves. Science 262:885-889.

Swetnam, T.W. and J.L. Betancourt. 1998. Mesoscale disturbance and ecological response to decadal climatic variability in the American Southwest. Journal of Climate 11,3128-3147.

Turner II, B. L., Kasperson, R. E., Meyer, W. B., Dow, K., Golding, D., Kasperson, J. X., Mitchell, R. C., and Ratick, S. J. 1990. Two types of global environmental change: definitional and spatial-scale issues in their human dimensions. Global Environmental Change: Human and Policy Dimensions 1 (1): 14-22.

Vitousek, P. M., Mooney, H. A., Lubchenco, J., and Melillo, J. M. 1997. Human domination of earth's ecosystems. Science 277 (5325): 494 - 499.

Benefits of Nonfacilitated Uses of Wilderness

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Abstract—Using the taxonomy of personal benefits attributed to wilderness and developed for the 1985 national wilderness conference, this paper summarizes the research since published on the benefits of nonfacilitated uses of wilderness. It describes recent developments in theory and methods regarding leisure experiences and discusses the implications of these developments for understanding wilderness benefits. The paper proposes that results of research on the benefits of wilderness can facilitate an outcome-focused approach to wilderness management.

An earlier state-of-knowledge review of wilderness benefits was written about 15 years ago by Driver and others (1987). Since that time, the number of acres in the National Wilderness Preservation System (NWPS) has increased from 89 million to over 104 million acres. This is a sizable hunk of "real estate" that is larger than many sovereign countries, and other large tracts of private and public land that could qualify as wilderness are not a part of the NWPS. While the on-site recreational use of the NWPS remained relatively constant during the 1980s, it has grown steadily in the 1990s (Cole 1996). This means that more and more people are realizing benefits from wilderness. More importantly to this paper, other more difficult to measure benefits of wilderness have been defined and better understood during the past 15 years. These "newer" benefits include spiritual growth/renewal of the human spirit; improved environmental/ecological learning, education and appreciation; maintenance and promotion of mental and physical health; a perception of one's sense of fit in the grand scheme of things; and promotion of environmental stewardship and ethics. In addition, since 1985, there have been wider appreciation and better understanding of the benefits of wilderness to the off-site users. Those off-site benefits include the proximity of wilderness and other natural amenities as a source of community pride and satisfaction, the economic value of wilderness-related tourism and, very importantly, the species diversity, sustainable ecosystem and natural laboratory values of wilderness.

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Purposes

Because of the expanding array of benefits, wilderness allocation, management and protection remain important public concerns. Put differently, we would not have the NWPS if these multiple benefits were not perceived. Therefore, understanding these benefits is fundamental to effective, efficient and responsive wilderness management. This paper addresses one category of these benefits, which we identify as the benefits of the nonfacilitated uses of wilderness. We will describe what is known scientifically about those benefits and relate knowledge about them to wilderness management. We will also explain the types of additional research needed.

Scope

Two papers in this proceedings examine the benefits of wilderness. The one by Ewert and McAvoy considers those benefits that accrue from facilitated, group-sponsored wilderness engagements where the sponsoring group, in advance of the trip, defines and establishes goals for the engagement. These goals are typically defined in terms of expected and desired outcomes, impacts or benefits, for which programs of actions/activities have been planned and are implemented to help assure realization of the preset goals and outcomes. These wilderness outings include those sponsored by the National Outdoor Leadership School, Outward Bound, Wilderness Vision Quest and outings planned and sponsored by institutions that use wilderness as some form of treatment, whether for at-risk youth or for patients/people under the care of some type of clinician. Also included are trips sponsored by churches, YM/WCAs, scout groups, etc., for which the degree of programming might not be so great.

Our paper addresses the benefits of wilderness realized by people other than those in group-sponsored, facilitated engagements. This category includes the off-site and the on-site users, typically referred to as the general public, whose visits to wilderness are usually composed of family or informal, small friendship groups. Generally, these individuals know each other before the trip and are unguided, with the exception of members of commercially organized outings such as hunting and float trips. As such, this paper focuses on the benefits realized by individuals who visit wilderness alone or in small groups and who do not follow any kind of imposed program or curriculum. While our focus is on the personal benefits realized individually by the on-site users,

we consider briefly the benefits of wilderness to off-site users and to the biophysical environment.

There will be some overlap in the types of benefits described in this paper and the one by Ewert and McAvoy, simply because members of sponsored groups receive some of the same types of benefits that the nonfacilitated users do, and vice versa. We see this as no problem because that overlap emphasizes the wide array of benefits provided by wilderness.

The Driver and others (1987) paper explained why an understanding of the benefits of wilderness is important; developed a taxonomy of such benefits; provided a lengthy review of empirical, philosophical and anecdotal evidence of wilderness benefits; and concluded with a discussion of how uniquely dependent these benefits are on wilderness. Because this paper draws heavily and builds upon the Driver and others paper, we urge the reader to become familiar with it. That is important because we modify slightly some of the concepts and conclusions of that earlier paper; to avoid redundancy, we assume the reader is familiar with the results of the empirical research about benefits contained therein. Specifically, we generally only cite studies and philosophical/conceptual articles about wilderness benefits published since 1985 (the Driver and others paper shows only one reference dated 1986 and most of them predate 1984). However, we do try to provide additional support for the Driver and others findings when it is warranted. In particular, we introduce some research approaches and managerial frameworks that did not exist or were little developed in 1985. Finally, when we believe the evidence warrants, we revise the conclusions of Driver and others.

To the extent that the scope of our paper permits, we pay particular attention to recent work on the six benefits that Driver and others felt were central to a wilderness philosophy. These were the value of wilderness as ideal places for learning about, appreciating and sustaining life, species diversity and natural ecosystems; the spiritual values of nature; the aesthetic values that go beyond scenic beauty to the sublime; the ethic of constraint that recognizes that populations of nonhuman organisms have rights to exist; historical and cultural values of our nation nurtured in wilderness, such as freedom, creative inspiration and pride in our natural bounty and splendor; and specific recreational experiences commonly sought in wilderness settings, such as challenge, skill-testing and self-sufficiency in a serene and primitive setting.

We end our discussion by recognizing the need to overtly manage wilderness to provide opportunities for realizing the benefits discussed by adopting an "outcomes-oriented approach" to wilderness management. We also emphasize the need for additional research to provide a more solid foundation for the proposed focus on outcomes in wilderness management.

Definitions

The above discourse has used the words "wilderness," "benefits" and "on-" and "off- site users." Because each of these words is used in different ways to mean different things to different people, we must define how we use them.

Wilderness

Since passage of the 1964 Wilderness Act, most land managers in the United States tend to think of wilderness as areas that have been designated as wilderness and are now included within the NWPS. We certainly include most of the acreage of those areas in the concept of wilderness, even though some parts of the existing NWPS are really buffer strips, not wilderness as we define it. However, we must take a broader perspective, because many of the benefits of wilderness considered here can accrue from wilderness areas not included in the NWPS. For that reason, we adopted the following definition of wilderness, used in the earlier state-of-knowledge paper on the benefits of wilderness by Driver and others (1987).

> ...wilderness has more to do with the contour lines in our heads than with those on maps; it exists, in other words, in the eye of the beholder. And there are a lot of beholders, which makes for a lot of definitions....Thus, any attempt at a definition is arbitrary....Included here will be *relatively large land areas that are neither easily accessible nor frequently used by motorized vehicles, where opportunities exist for primitive types of recreation, and past and current human activities are not readily noticeable. The concepts of spaciousness and wildness are central* [emphasis added to denote the definition of wilderness we use in this paper].

To reiterate, we are not limiting our attention to areas within the NWPS.

Benefits

Both of us have been closely associated with the development and refinement of the parks and recreation management system called "benefits-based-management." During those efforts, we discovered that the word "benefit" is not as clear as we first thought. One semantic difficulty is caused by the specialized way that economists use the word "benefit" to refer to an economic, usually monetary index or metric of the worth of a good or service. A second difficulty is that people often interchange the concepts of benefit, value and meaning. Third, all of the many dictionaries we consulted define a benefit as an improved condition or a gain, which we now consider as only one type of benefit that accrues from the management and use of recreation and other amenity resources, including wilderness.

A second type of benefit occurs without any improvement or change in condition because just the maintenance of a desired condition—and thereby the prevention of an undesired or unwanted condition—is beneficial. Examples include maintenance of: one's physical or mental health or friendships with close associates; community stability, cohesion and pride; or desired ecological processes of the biophysical environment. In addition, managers of recreation and other amenity resources strive to provide opportunities for people just to enjoy satisfying psychological experiences, whether or not they realize an improved condition or maintain a desired condition. For example, any improved or maintained condition realized from watching a beautiful sunset is hard to identify and define, but it is certainly satisfying.

For this reason, we decided that people benefit if they realize a satisfying psychological experience while recreating, which constitutes the third type of benefit. Such

enjoyment need not denote either an improved condition or the maintenance of a desired condition, but it must be recognized that one person's satisfying experience at a particular point in time (for example, being with a crowd of people) might not be satisfying to that person at another time or to another person at the same time.

In summary, we recognize three types of benefit—an improved condition, maintenance of a desired condition (and thereby prevention of a worse condition) and realization of a satisfying psychological experience. It should be emphasized that the first two types of benefits can accrue to individuals, groups of individuals (families, communities or society a large) or the natural or biophysical environment, with the last being a primary concern of wilderness managers. The last type of benefit—satisfying psychological experiences—is relevant only to individuals. For a detailed elaboration of these three types of benefits, see Driver and Bruns (1999).

On- and Off-Site Users

When people think about the benefits of wilderness, they generally concentrate on the benefits realized by the on-site users, those who physically visit and enter the areas. However, several studies have documented that only small percentages (usually not more than about 16%) of the population of the United States actually visit wilderness areas. But surprisingly, 85-90% (with the percentages varying from study to study) of the respondents to at least three national or regional household surveys that focused on wilderness use and values reported that they valued the existence of wilderness and were willing to pay reasonable taxes for such—and remember that no more than 16% said they actually had visited wilderness areas. It is reasonable to assume that the very large numbers of off-site users with this willingness to pay realize sizable personal benefits just from the existence of wilderness. While little research exists to document the nature and scope of these benefits, they likely include the off-site users' vicarious appreciation of wilderness, their latent demands to sometime visit wilderness areas, the satisfactions they derive from watching wilderness scenes—and the associated plants and animals dependent on those natural ecosystems—on TV or seeing pictures of them in coffee-table atlases and their good feeling about the stewardship benefits they derive from wilderness preservation.

In addition, several studies have documented that peoples' perceived satisfaction with and/or quality of their lives is strongly influenced by the presence of nearby amenities, including nature-based amenities (Marans and Mohai 1991). It is reasonable to assume that these amenities include nearby wilderness areas. While we generally lack scientific understanding of the nature, scope, and magnitudes of the benefits of wilderness to the off-site users, those benefits in total probably exceed those realized by the on-site users, simply because of the much greater number of off-site users. There certainly would not be an NWPS of over 104 million acres without the support of off-site users. Thus, these benefits cannot be ignored. For this reason, when we refer to the benefits of wilderness, we are thinking of benefits of the preservation, use and appreciation of wilderness.

Some Perspectives Since 1985

In the introduction to their paper on wilderness benefits, Driver and others (1987) noted several limitations of past research addressing such benefits. These included recognition that: (1) some types of benefits had probably not yet been identified; (2) almost all studies had used self-reports in questionnaires of users' subjective appraisals of benefits or benefit-implying preferences, with too few studies using other triangulating methods such as physiological responses; (3) many studies purporting benefits had been poorly designed, often lacked control groups, a longitudinal design and/or were based on small and nonrandom samples; (4) there have been too few studies of the benefits of wilderness to off-site users; and (5) it was often difficult to determine, based on the study design, whether the benefit was attributable, especially uniquely attributable, to the wilderness setting.

Now, as we reach the new millennium, some advances have been made in the areas that concerned Driver and his associates back in 1985, when their paper was drafted. For example, with the support of many associates, Driver has sponsored major conferences and published two important books on benefits in the 1990s: Benefits of Leisure (Driver and others 1991) and Nature and the Human Spirit (Driver and others 1996). Cordell and others (1998) reported on wilderness values as a means to begin to understand the off-site benefits of wilderness in results of a national household survey of the American public. About 55% felt there was not have enough designated wilderness, a far larger percentage than actually visit wilderness, and only 2.5% saying we had too much. The respondents to that national survey rated the ecological and environmental protection values of wilderness most highly; about 70% said these outcomes were very or extremely important. About 60% rated the scenic, existence and option-to-use values of wilderness also as very or extremely important. About 50% rated protecting wilderness for its recreational opportunities as very or extremely important, while 45% rated the spiritual values of wilderness at that level. Thus, while the American public does not value the personal benefits of wilderness as highly as the environmental protection values, about half say the wilderness benefits of most concern to this paper are very or extremely important.

We have ignored other issues of concern to Driver and others in 1985, lost ground or purposefully turned our attention in other directions. For example, we have done few or no studies to determine the wilderness dependency of many of the benefits identified back in 1985. As a profession, we have sat idly on the sidelines even as the wilderness idea has come under unparalleled criticism (for example, see Callicott and Nelson 1998). Others have recently argued that some purported benefits of wilderness, such as environmental awareness, immersion in nature and nurturing of a land ethic, might be better learned in one's backyard or in one's garden than in wilderness (Cronon 1995).

Also ignored has been the criticism that most studies of wilderness benefits have lacked adequate design. Most studies of the personal benefits of wilderness in the late 1980s and the 1990s were one-shot case studies, lacked control groups and involved subjective self-assessments of benefit.

But there have been useful research paradigms and methodologies employed since 1985. For example, some social/behavioral scientists have become more interested in gaining a deeper understanding of the "total" wilderness experience-that is, in understanding the nature and process of personal experiences/benefits as they unfold in context, across time and as a person-environment transaction. One example is the pioneering work of Scherl (1990). Expansion of this perspective represents a significant theoretical contribution to recreation and related amenity research in the 1990s.

This broader perspective builds on the behavioral model of recreational engagements developed in the 1960s by Driver and Tocher (1970), and it recognizes that a recreational engagement has many phases across time and benefits flow before, during and after the on-site engagement (Clawson and Knetsch 1966; Driver and Tocher 1970). It incorporates, but goes beyond the work by Driver and his associates that identified and quantified the motivational bases for recreation choice specified by the Recreation Experience Preference scales (Driver, and others 1991; Manfredo and others 1997) and evaluated the attributes of settings and kinds of activities that shape these experience preferences. The newer and broader paradigm emphasizes that the total recreational experience is emergent; it ebbs and flows; it is highly personal; and it results from transactions between and among the person, the situation and the environment. By focusing on the total experience, these transactions not only shape and define the experience on-site; they shape and define the experience off-site. Thus, they shape and define the benefits (and nonbenefits) realized throughout the total experience because, as said in the section on Definitions, the third type of benefit is realization of a satisfying experience, whether that satisfaction occurs on- or off-site.

Because the broader perspective about the total experience places much greater emphasis on the highly individualistic and unfolding aspects of experiences, it has tended to reinforce the subjective self-appraisals of benefit. But adoption of this approach does not mean that we do not need other types of studies that use physiological and other measures, especially longitudinal studies. Instead, we need a variety of methods to triangulate the experience and benefit constructs so important to understanding the personal benefits of wilderness and to quantifying them.

A final important development since 1985, which we will touch on near the end of this paper, is an outcomes-focused framework to guide recreation and related amenity resources. That framework is based on our belief that the underlying purpose of any type of management is to optimize provision of clearly specified opportunities so that benefits can be realized. By analogy, the managers of other public resources, such as those that provide educational and health-related benefits, must understand what benefits they are expected to provide and how opportunities for their realization can best be provided. Thus, when applied to wilderness management, the outcomes-focused framework requires the same approach, which mandates that managers understand what the benefits of wilderness are and manage explicitly to optimize net benefits, or to the extent feasible, maximize benefits and minimize negative outcome or disbenefits.

State of Knowledge Since 1985

Benefits to be Considered

Our discussion of changes in the state of knowledge about nonfacilitated uses of wilderness since 1985 focuses on the personal benefits realized by on-site users. To be comprehensive, we also consider the most important social benefits to off-site users, such as those that promote local community satisfaction and economic stability and growth. Because of their great importance, we also comment briefly on the environmental/sustainable ecosystem benefits of wilderness.

Table 1 lists the personal benefits of the nonfacilitated uses of wilderness that we examine. The taxonomy is nearly a duplicate of the list given as table 1 of the Driver and others (1987) state-of-knowledge review. For some categories, we added subheadings to reflect additional thought or empirical research on the topic. We dropped other categories that are beyond the purview of this paper or have been subsumed under another category or heading. We purposefully retained much of the Driver and others taxonomy because it was based on a large number of research projects conducted from the mid-1960s to 1985, and it permits us to more clearly demonstrate both the continuity and change in wilderness benefit research and findings over the past 15 years.

Table 1—Taxonomy of personal benefits of wilderness.

A. Developmental
1. Self-concept/self-identity
2. Skill development
a. Outdoor skills
b. Adventure
3. Self-actualization
B. Therapeutic/mental health
C. Physical health
D. Self-sufficiency, independence
1. Self-reliance
2. Primitive living
E. Social identity
1. Family kinship
2. Group cohesion
3. Social recognition
F. Educational
1. Nature learning
2. Environmental ethic
3. Environmental stewardship
G. Spiritual
H. Aesthetic/creativity
1. Nature appreciation
2. Aesthetic appreciation

Continuation of Research Measuring Preferred Recreation Experiences

Prior to the early 1980s, most measures of the personal benefits of wilderness employed post-trip self-reports of respondents' perceived realization of recreation experience preferences. The logic then was that the users benefited from the satisfying experiences they realized. The methods generally involved collecting names and addresses of the respondents as they were leaving the wilderness areas and recording their most frequent recreation activities. Several months later, after the most important recollections were supposedly stored in their minds, the respondents were mailed a questionnaire, asking them to (1) imagine that they were going to visit the same area next year and engage in the their previously identified major activity, and (2) rate how satisfying or unsatisfying each of the experience preferences (perceived benefits) listed in the questionnaire would be on that future trip. The logic was that the most salient benefits could be recollected fairly accurately, as guided by the wide variety of possible experiences listed.

Results of these types of studies were summarized in Driver and others (1987). Reference to table 1 of that paper shows that there were similar preference patterns for certain highly valued experiences across the 12 designated and undesignated wilderness areas studied across the United States. Put differently, on the average, the five to seven most highly valued perceived benefits were almost always ranked the same across all 12 areas. By order of perceived contribution to respondents' satisfaction, the most highly rated perceived benefits were enjoyment of the natural setting, enhanced physical fitness, general tension release, temporarily escaping the noise and crowds of people back home, outdoor/environmental learning, sharing similar values with close friends and a feeling of independence and self-sufficiency. Each of these benefits is listed in our table 1, sometimes under other names.

In our review of the literature for this paper, we found only five studies published since 1985 on recreation experience preferences of wilderness users, at four areas. Results of two studies of areas administered by the Bureau of Land Management in Colorado, Ruby Canyon-Black Ridge (Stein and Lee 1995) and America Flats (Virden and Knopf 1989) were very similar to the results of similar studies reported by Driver and others (1987), despite the fact that most of these areas, while largely undeveloped, would not qualify as wilderness as defined above. Two other studies using a similar research design focused on rather specialized mountain climbers at Mount Rainier National Park (Ewert 1985) and McKinley National Park (Ewert 1993,1994). Not too surprisingly, these studies showed that the mostly highly valued perceived benefits were related to being in those settings suited to technical climbing, challenge, risk taking, exhibition (social status), locus of control and catharsis.

These studies suggest that the preferences of recreationists for at least certain kinds of perceived benefits do shape their preferred settings for the activity. For example, at the American Flats Recreation Area, recreationists who scored higher on achievement preferences tended to prefer a primitive setting, and this was true for individuals who preferred hiking or angling. Those whose first activity choice was hiking or camping and who had stronger desires to share/lead others also more strongly preferred a primitive setting. In contrast, those who preferred angling and scored highest on sharing/leading others were least likely to prefer a primitive setting. Finally, no matter what the preferred activity, recreationists with the lowest preferences for social support were most likely to prefer a primitive setting (Verdin and Knopf 1989).

Stein and Lee (1995) identified four groups of recreationists at the Ruby Canyon-Black Ridge area on the basis of their benefit-implying experience preferences and found that at least some of the groups differed on certain setting preferences. For example, the two groups that scored highly on stress relief/fitness/nature appreciation, achievement/stimulation and independence, and lowest on meeting new people, preferred to recreate in large, undisturbed natural settings, with little contact with other people and few facilities, much more than the other two groups did.

Ewert's work on Mt. McKinley climbers (1993) suggests that success at reaching the top strongly influenced benefit-implying trip motives. Those who successfully reached the summit scored significantly higher on exhilaration/excitement, accomplishment, social aspects (such as being part of a team and helping others) and image and recognition. In contrast, those who failed to reach the top scored higher on slowing down/disengaging from normal life and on scenery/wilderness appreciation. Guided trip members scored higher on exhilaration/excitement than climbers on independent and solo trips; the guided trip members were also significantly more motivated by social aspects of the trip than the solo climbers. Finally, guided trip members reported higher experience nature/wilderness motives than the solo and some independent climbers.

In summary, the relatively few studies done since 1985 on the recreation experience preferences of visitors in nature-based recreation areas continue to provide evidence that nature appreciation, escape, stress reduction, physical fitness and environmental learning are extremely important perceived benefits. Other benefit, such as family kinship, group cohesion and sense of independence, also remain important. Other benefits shown in table 1, such as those related to spiritual growth and renewal and skill development, were rated somewhat positively, but were not considered nearly as important, except the importance of challenge to the specialized mountain climbers studied by Ewert (1985,1993,1994).

Thus, as in the past, we continue to find that desired trip outcomes vary by type of group and activity. For example, while the mountain climbers strongly sought exhilaration, risk and achievement, guided climbers had different experience preferences than unguided and solo ones. The recent studies also continue to suggest that, while wilderness or wilderness-like conditions may not be necessary for achieving preferred benefits; many types of recreationists seeking certain identifiable benefits do prefer and seek out primitive settings for their activities—an important point to which we will return in the section, Setting Dependencies of the Benefits.

Given this consistency in the types of what we call the overall most salient perceived benefits sought, as revealed by the recreation experience preference research, leisure

scientists concerned with the total recreation experience, as defined above, have recently employed other methods to evaluate it. As noted, this has been done to better understand the entire experience and how that experience unfolds during the different phases of the recreation engagement-from planning through actual engagement to recall. These studies are usually done while the recreationist is on-site instead of with post-trip surveys. These typically more qualitative methods are considered by the scientists who use them as less obtrusive and less structured than the other methods, such as the Recreation Experience Preference scales.

However, as with the more structured methods, some cautions must be raised. First, the people doing the research can still strongly influence the results just by their presence and demeanor and by the types of instructions given. Second, because users' responses are so rich and varied, the highly qualitative/subjective results can be (and have been, in some instances) interpreted differently by different researchers analyzing the same data sets. Third, without control groups, it is impossible to know how much the settings in which the studies are done actually influenced the responses or whether similar responses would have been given for different settings—a problem with most, if not all, types of self-report methodologies to which we return shortly.

The discussion of the results of these various methods is organized by the categories of benefits listed in our table 1.

Developmental Benefits

This category of personal benefits refers to any positive changes in on-site wilderness users' self-concept/self-identity, skill development and self-actualization from nonfacilitated trips. Skill development includes outdoor or "woodsman" skills and skills for "adventuring" or "mountaineering."

Self-Concept/Self-Identity Benefits

Williams and others (1988) make a distinction between self-esteem, or self-concept, and self-definition, or self-identity, and discuss how wilderness contributes to each. Self-concept refers to our evaluation of how good we are, and self-definition deals with the issue of who we are. Both a positive self-concept and clear self-definition are critical to healthy human functioning, but self-definition seems to be one of the most fundamental requirements for successful human development. Self-identity both clarifies who we are for our own sake and serves to define or interpret ourselves to others. Both forms of self-definition require constant maintenance, and affirming our identity is as important to growth and development as enhancing our feelings of self-worth (Williams and others 1988).

Some people believe strongly that wilderness environments, as physical places or as symbols, are ideally suited to the development of identity and a sense of self-worth. They argue that in wilderness, there is an almost endless supply of mountains to be climbed, lakes to be navigated, food to be collected, wildlife to be cherished, weather to be confronted and insects to battle. They propose that there is, ideally, almost complete freedom to meet these "challenges" as one sees fit. Thus, for them, wilderness is an ideal place to test and define themselves as more or less rugged, adventurous, poetic, wild, self-sufficient and a host of other human attributes.

In addition, wilderness, either as place or as symbol, can contribute to our cultural definition of self and to our sense of biological self as members of the human species in the community of life. Nash (1982) has argued that the development of our nation out of wilderness helps us to define ourselves as Americans, a people who are rugged individualists, pioneers and creative problem-solvers, and who can act to get things done.

Finally, some people argue that in wilderness, perhaps more than in any other place, humans can feel and act as vital members of the web of life. At least ideally, we can observe, sense and act again in such vital biological relationships as predator or prey; we can feel and perhaps observe ancient rhythms of geological time, and, in moments of deep immersion, we can feel the timelessness of endless time.

Others view these arguments as romantic and suggest that self-identity is more socially constructed and, if not, there are many alternatives to wilderness to promoting self-identity. They also point to countries that do not have much wilderness, such as The Netherlands, and say folks there are doing quite well, thank you.

The answer to this debate is that we do not really know which side is right, simply because these issues remain little studied. This is probably because studies of self-concept are fraught with difficulty, especially because it is known that a person's self-concept changes very slowly, and problems of extinction of any noted changes over time are characteristic of most findings in past studies of self-concept/identity. But there has been some progress.

Driver and others (1987) reviewed the research on self concept/self-sufficiency and concluded that there is some evidence of these types of benefits, especially for the more facilitated forms of engagement such as in Outward Bound, but that more studies are needed.

Talbot and Kaplan (1986) studied individuals who participated in a nine-day Outdoor Challenge Program that centered on the natural environment and closely resembled a typical backpacking excursion. Over time in the wilderness setting, participants gradually noticed more of nature's details, felt increasingly comfortable in the woods, felt increased awe and wonder about nature and, important here, gradually felt like they knew themselves better. The individuals' developing perceptions had direct consequences on their views of their own abilities and interests; the experience seemed to shape their definitions of who they were as individuals.

Journal entries of participants in the Talbot and Kaplan (1986) study also suggest that for some, the experience in nature helped them to connect with the biological self. About 26% of the sample felt a sense of oneness with the environment, felt close or related to the earth and its animals. Another 16% felt a sense of environmental coherence or harmony, including feelings that it was all part of a system and that nothing was either good or bad. These feelings and insights border on the spiritual, which is discussed in a section below.

Arnould and Price (1993) studied the evolving adventure and lived meaning of an extended river rafting trip on the Colorado River in the Grand Canyon. One of the three important themes that explained trip satisfaction, both as it

unfolded and after its conclusion, was personal growth and renewal of self. Guides worked with the wilderness environment to provide rafters with a sense of both great serenity and imminent danger. Participants internalized the sense of danger and the exhilaration of obstacles overcome. This helped them crystallize their sense of self and emerge from the trip with a sense of mastery and enhanced competency. Post-trip measures weeks or months after the trip contained many allusions to increased self-awareness, self-discovery and personal transformation as highlights of the trip.

The river rafters also gradually developed a deep sense of communion with nature, often facilitated by the guide's efforts. For many, this connection was deeply spiritual. But for many others, this communion seemed a development of the biological self. The water provided a profound experience of nature for some; for others, it was the geology or the wildlife. With the help of guides, participants gradually moved to "river time," getting up with the sun and going to bed when the sun went down.

Borrie (1995) used the experience-sample method to measure Okefenokee Wilderness users' connections with nature and the biological self in real time. Through measures taken multiple times during the experience, participants expressed moderate levels of feeling connected to and immersed in nature, but these feelings increased across time. They also felt a strong sense of timelessness throughout the experience; the scale measured a lack of concern for watches and knowing what time was. This may suggest a move to "sun time," a shift to moving to diurnal rhythms. This suggests deeper connection with the rhythms of nature, but it almost certainly does not indicate the sensing of a geological time horizon.

McIntyre (1998) replicated Borrie's study and methodology in a wilderness setting in Australia and obtained similar results. His respondents felt a strong sense of timelessness; their sense of oneness with nature was somewhat lower than that of Borrie's study participants. McIntyre also related level of activity in wilderness to the measures of biological self. Feelings of timelessness were greatest when the respondents were passive. In contrast, feelings of oneness with nature were much higher when the recreationists were actively engaged with the environment than when they were passive (that is, resting or sitting quietly) or engaged in maintenance activities such as cooking or eating.

Skill Development

Intuitively, wilderness seems like an ideal place for adventure and outdoor skill development. People there are on their own with no help from modern conveniences. The wilderness environment is also inherently complex and challenging. Yet, in 1987, Driver and others found only "a little importance" given this benefit, which was a part of the achievement domain in their categories. More recent studies evaluating this construct more specifically indicated its importance.

In the Talbot and Kaplan study (1986), participants in the Outdoor Challenge Program recalled that learning camping activities were some of the most enjoyable aspects of the trip. They expressed amazement and satisfaction at how quickly they felt comfortable in the woods.

Personal growth through the acquisition of new skills was a major theme in participant journals on the river trip in the Grand Canyon (Arnould and Price 1993). Progressive mastery over novel things and tools began at the put-in and continued throughout the entire trip. Acquired skills included learning to pack a dry bag, how to load and unload the raft, how to attach a life jacket, how to use other safety equipment, how to paddle, how to negotiate difficult rapids and how to cook over a campfire. Recollections of the trip included many statements of satisfaction at being able to handle the trip (camping/rapids), of being able to kayak down rapids and still feel somewhat in control and of becoming more and more comfortable with the risks involved.

Patterson and others (1998) recently reported a hermeneutic approach to understanding the nature of canoeists' experiences in Florida's Juniper Prairie Wilderness. With this research approach, respondents describe their experiences and what made them meaningful. Four general themes seemed to describe the experience, and two, challenges and decisions not faced in everyday life, were related to adventure and skill development. The most prevalent experiential dimension was challenge, but the meaning of challenge varied greatly. For some, the challenge of tortuous twists and turns while canoeing Juniper Run was frustrating. For others, it was a positive aspect. For yet others, it seemed initially negative, but as the interview unfolded, respondents began to construct the experience as a positive one. This suggests that even frustrating experiences can be redefined as beneficial. But we do not know how much of this is dissonance reduction.

Among the important aspects of decisions not faced in everyday life were way-finding and facing the unknown. Because of the nature of the river, with its twists and turns and many channels as it flows through a dense, semitropical forest, many respondents experienced the sensation of being lost, either in space or time. Again, the meaning of these sensations was interpreted differently across individuals and within individuals across time. These different responses to adventure and challenge likely relate to skill levels, but, more importantly, they probably shape benefits and disbenefits very differently.

Self-Actualization

Self-actualization was defined by Maslow (1968) as someone operating at the peak of his or her potential, when effective functioning is optimal and where the individual is being all that he or she can be. Maslow goes on to describe peak experiences as "moments of highest happiness and fulfillment," often achieved through the nature experience, aesthetic perception, creative movement, intellectual insight, organismic experience, athletic pursuit and the like.

Wilderness, because of its naturalness, solitude and awe-inspiring qualities, is viewed by some people as ideal for fostering peak experiences. Such advocates of wilderness as John Muir and Sigurd Olson describe their own epiphanies in wilderness as moments of such transcendence.

But there are few empirical studies of the apparent self-actualizing benefits of wilderness. Driver and others (1987) did report the results of a panel study (Young and Crandall 1986) of the degree of self-actualization among users of the Boundary Waters Canoe Area Wilderness. Both more frequent and less

frequent BWCA users increased in a self-actualization score from 1979 to 1984, but the more active users in the panel increased more. This is a bit of evidence that wilderness, or some other moderating variable, may provide more opportunities for peak experiences.

While we know of no studies of self-actualization in wilderness in the 1990s, the profession has been increasingly interested in psychologically deep experiences in nature. One recent development has been expansion of the conceptualization of optimal experiences to include flow and absorption (Csikszentmihalyi and Kleiber 1991). Flow experiences are characterized as a centering of an individual's attention, transitoriness, richer perception, forgetting oneself and becoming totally involved in the activity at hand, disorientation in time and space, and enjoyment and momentary loss of anxiety and constraint (Mannel 1996). Csikszentmihalyi (1990) describes moments of flow as the best moments of our lives. To our knowledge, flow experiences have not been measured in wilderness before or since 1985.

Quarrick (1989) indicates that during absorption, sense of self and time fades as the person merges with a fascinating stimulus. Kaplan and Kaplan (1989) believe that while absorption can occur with a wide variety of stimuli, natural objects may be especially fascinating. Walker and others (1998) recently related the level of optimal experiences, as measured by degree of absorption, attained by visitors to a forested national recreation area to the off-site benefits attained by individual recreationists. As a group, respondents achieved absorbing experiences at moderate levels, and these experiences were related to post-visit measures of meaning, social interaction and knowledge benefits in real but complex ways. Achieving the highest level of absorption on-site did not always result in the highest post-trip benefit. Moderate levels of absorption seemed to be best.

Therapeutic and Mental Health

No benefit of nature encounters has been so thoroughly researched and documented as the stress relief/mental health outcomes. This was true in the Driver and others (1987) review; it remains the case today. Escape from stresses of everyday life and search for privacy and solitude remain among the most important motivators of wilderness visits.

Three major sustained efforts have documented the research on mental health/healing: work on the restorative benefits of nature by the Kaplans and their colleagues (Kaplan 1995; Kaplan and Kaplan 1989); Ulrich and his associates (Ulrich and others 1991a; Ulrich and others 1991b); and Hartig and his associates (Hartig and others 1991). Because more (but certainly not all) of the Kaplans' work was done in wilderness or wilderness-like settings, we begin there.

Kaplan (1995) describes four critical components of restorative environments: being away, fascination, extent and compatibility. Wilderness settings, while certainly not the only places available for restorative experiences, certainly qualify for them. Wilderness, by definition, in America is "away." Nature is well endowed with objects and processes that readily hold attention; little effort is needed to attend to nature's fascinations, and the mind is free to wander and wonder. By definition, wilderness has extent. In wilderness, people have the opportunity to wander in space and time. For many, the natural environment is highly compatible. Many would argue that the predator role (hunting or fishing), the gathering role (collecting blueberries), locomotion (hiking or boating), domestication of the wild (gardening or caring for pets), observation of other animals (bird watching) and survival skills (setting up camps, way finding) are among the most deeply essential, the most deeply seated and therefore the most natural of all human activities. While wilderness, at least in its current American conception, doesn't provide opportunities for all of these behaviors, it certainly is a good place for most of them.

Talbot and Kaplan (1986) found that participants in their nine-day Outdoor Challenge Program felt refreshed and restored during and as a result of their experience. About 24% mentioned in their journals feeling mentally and physically renewed, very relaxed and alive.

Hartig and others (1991) found that wilderness vacationers showed improved proofreading performance, a task that demands attention, after the trip, while the performance of comparable groups of nonwilderness vacationers and nonvacationers actually declined. Interestingly, the wilderness vacationers' overall happiness scores were the lowest of the three groups at the post-trip measure (re-entry blues?), but three weeks later, their scores had rebounded to the highest level. In a second study reported in the Hartig and others paper (1991), participants completed tasks that resulted in cognitive fatigue. Then subjects received one of three treatments: a walk in a nature area, an urban walk, or passive relaxation. Subjects in the natural area rated their environment as more restorative, in terms of being away, fascination, coherence (an aspect of extent) and compatibility. They also had higher overall happiness and lower feelings of anger and aggression.

Ulrich's view of restorative experiences suggests that nature has a calming effect because it is a nontaxing stimulus that elicits deep-seated and almost automatic positive emotional states and blocks negative or taxing feelings (Ulrich and others 1991a). To test these notions, Ulrich and Simons (1986) and Ulrich and others (1991b) first showed study participants a stressful movie and then presented color/sound videotapes of different natural and urban settings. Stress recovery was measured during the environmental presentations with self-ratings of feeling states and by four physiological measures. Findings from both the subjective and physiological measures showed that recovery was faster and more complete during exposure to the natural scenes, as opposed to the urban environments. But it should be noted that those natural areas were far from being wilderness.

Other studies suggest that even glimpses of nature can have healing effects. For example, Ulrich (1984) found that hospital patients recovering from surgery had more favorable postoperative recovery if they had a window view overlooking trees. Prisoners with cell views of nature had fewer sick calls and fewer stress symptoms such as digestive illness and headaches (Moore 1982; West 1986). Finally, Katcher and others (1984) found that stress associated with dental surgery could be reduced by passive concentration on natural content (such as an aquarium).

We conclude our discussion of stress relief values of nature encounters with two precautionary statements. First of all, the work of Ulrich and his colleagues cannot be directly generalized to the stress relief benefits of wilderness visits. However, the mechanisms involved in stress reduction in wilderness and "near-nature" environments are likely the same. Second, all encounters with nature are not necessarily stress-reducing. Some may even be stress-causing. Wilderness visitors who experienced 100 mph winds in their canoes or huddled in their tents during the July 4, 1999, storm in the Boundary Waters Canoe Area Wilderness likely experienced high levels of anxiety and stimulation overloads. Specifically, Bunting and others (1986) found that both self-reports and physiological measures indicated that inexperienced individuals who engaged in rock climbing and rappelling had high stress levels both before and after the activities. This was true for both physically fit and less fit subjects, with the less fit individuals experiencing the highest stress levels. This suggests a lack of compatibility between the perceived risk and perceived competencies and indicates a strong negative psychological reactance.

Physical Health

Physical activity is beneficial and indeed essential to human health and survival (Paffenbarger and others 1991). Recreational exercise is a common way for Americans to keep physically fit, as seen by the participation rates in such activities as walking for pleasure, jogging and aerobic classes at the health club. Wilderness use requires physical exercise, and travel within wilderness is typically extended and aerobic. Studies of the experience preferences of recreationists in wilderness reviewed by Driver and others (1987) and those described earlier in this manuscript typically have placed the desire for physical fitness and physical health among the most important of all trip motives.

In their 1987 review, Driver and others were unable to cite any studies that physiologically measured the physical fitness values of contacts with nature. Instead, they mentioned that much research has documented the benefits of physical exercise, and they pointed out that wilderness hiking is good exercise and logically provides exercise-related health benefits. Since then, some progress has been made. Montes (1996) points to a growing body of evidence that indicates that gardening, caring for potted plants, watching fish in an aquarium or having a pet dog or cat can help reduce hypertension and offers other mental and physical health benefits.

Cimprich (1992, 1993) studied the recovery patterns of breast cancer patients. Such patients typically have difficulty remembering to carry out recommended care practices after discharge from the hospital and have coping problems and difficulties in interpersonal relationships. Participants who were part of an experimental group that participated in three short, restorative activities each week, typically nature-based activities such as walking in nature and gardening, showed significant improvement over a control group in attentional performance, inclination to start new projects and ability to return to work and to do so full-time.

Ulrich (1984) found that patients recovering from surgery who had a view of nature were able to leave the hospital more quickly than a comparable control group without such a view. In another study, Ulrich and Simons (1986) found that heart rate, muscle tension and pulse transit time (a systolic blood pressure correlate) subjected to stress recovered to normal very quickly in response to viewing a nature videotape. Heart rate accelerated during the urban exposure. These data suggest the possibility that natural settings elicited responses which included a parasympathetic nervous system component; such influences are associated with perceptual sensitivity and restoration of physical energy (Ulrich and others 1991b). The rapidity of recovery also suggests that relatively brief exposures to nature can restore vital bodily functions.

Hartig and others (1991) tested Ulrich and Simon's (1986) findings outside the laboratory. They randomly assigned students to a walk in a natural environment, a walk in an urban environment or a passive relaxation condition and measured their post-experience systolic blood pressure, diastolic blood pressure and heart rate. They found no difference in any of these physiological measures across the three groups. This finding may have been procedural. Researchers did not take the physiological measures until about 50 minutes after the experimental event. The quick recovery found by Ulrich and Simon may have already occurred, thus masking any effect of response to the experimental intervention. These findings, taken together, suggest that for some kinds of physiological benefits, engagements in wilderness, indeed even in nearby nature, need not be long.

Self-Sufficiency Benefits

Self-sufficiency includes two dimensions: self-reliance and primitive living. Robert Marshall (1930) applauded the opportunity for self-sufficiency in wilderness. Thoreau went to the woods "to live deliberately, to front only the essential facts of life,...to live deep and suck out all the marrow of life, to live so sturdily and Spartan-like as put to rout all that was not life" (Torry and Allen 1949). Olson (1938) observed and cherished how quickly a man in the Boundary Waters "sheds the habiliments of civilization and how quickly he feels at home in the wilds . . . now that he is back at the real business of living." Sax (1980) expresses this outcome as "you would like to emulate the pioneer explorers...you would like independently to raft down the wild Colorado as John Wesley Powell did a century ago. You would like to go it alone in the mountain wilderness as John Muir did."

We have evidence that people who visit primitive settings value these kinds of experiential outcomes (Driver and others 1987). We assume that those few solo hikers/climbers in wilderness are there in part to test their self-reliance. But we have surprisingly little research on whether people actually attain these benefits in this time of high-tech gear and synthetic clothing, especially in wildernesses where such late 20th century gadgetry as backpack stoves are mandated by regulations.

Participants in the Talbot and Kaplan (1986) study of an Outdoor Challenge Program listed the solo experience as one of the hardest things they did but also one of the best things they did. In addition, about 24% mentioned the simplicity of woods living, where days were reduced to a few simple tasks, as among the most meaningful of experiences.

Borrie (1995) assessed the feelings of primitiveness or "simple living" and "living like a pioneer" among Okefenokee Wilderness visitors at several moments during their trip

into the swamp. Such primitive living scores were quite low among his respondents, but they did increase progressively across time in wilderness.

Social Identity Benefits

The social identity benefit includes family kinship or bonding, group cohesion and social recognition. While wilderness use is commonly seen as the domain of the rugged individualist, people seldom visit alone. Recent research suggests that wilderness visitors spend much of their time in wilderness focusing on others in their group. For example, Borrie (1995) found that, among Okefenokee Wilderness users, focus on others and gaining acceptance from others in the group was as important as focus on the environment and much higher than focus on self, emotions and task. In the Juniper Prairie Wilderness of Florida, canoeists on a challenging stream on average focused more on the environment and task than on other people, but respondents gave much more attention to others than to their own thoughts and emotions (Borrie and Roggenbuck 1996). In Australian wilderness, McIntyre (1998) found that, over the course of the trip, concern about whether group members were accepting them was the most important wilderness experience mode, more important than task orientation, environmental awareness and introspection.

Clearly, visitors go to wilderness for social group benefits, and once there, they are very concerned about small and intimate group dynamics. Wilderness is a place where formality and role barriers are reduced. Often, group members become highly dependent on each other. These are conditions where establishment of trust, open communication and sharing of ideals and problems are enhanced and sometimes required. It is during these times that persons gain and share information about some of their most important decisions (Driver and others 1987).

Past research on experience preferences confirms that many recreationists seek family bonding and friendship with others of similar values in wilderness settings. These benefit preferences typically fall mid-range in importance, just below nature appreciation, fitness and stress relief values (Driver and others 1987). In contrast, the desire for social recognition or status from demonstration of skills usually scores low in experience preference checklists, except among certain groups such as technical mountain climbers. This may reflect a social bias against admitting that one wants to draw attention to oneself, but several cross-validating and unpublished tests by Driver of such social desirability bias in social recognition and other Recreation Experience Preference scales did not support the existence of such biases (Driver and others 1991). We do know that wilderness and primitive recreationists tell stories and share photographs of their enviable experiences with enthusiasm and joy, and the construction of stories begins during and immediately after the experience (Arnould and Price 1993, Patterson and others 1998).

The recreation profession has become increasingly interested in the family bonding benefits of leisure (see Orthner and Mancini 1991). However, we know of no measures of family kinship benefits of wilderness use other than those using the Recreation Experience Preferences scales. This represents one of the greatest deficiencies of all research on wilderness benefits. However, progress has begun in understanding small group behavior and bonding in wilderness. Heywood (1987) classified the different types of groups on river trips as primary, some (others) known and all unknown and found that they differed in their experience preferences for the trip. He also recognized that collectives (groups that combined people who were known and unknown to each other before the trip) faced very different challenges in achieving their desired experiences and benefits than groups of family or friends (Heywood 1990). He recommended a theoretical basis for understanding how collectives develop structure, use resources and develop activity patterns to attain their goals. This can help guides and outfitters better facilitate the achievement of satisfying experiences and beneficial outcomes for their guests.

Finally, recent research has begun to document group cohesion benefits. Arnould and Price (1993) found that *communitas*, or the evolving feeling of communion with friends, family and strangers, was among the most important themes of a river trip in the Grand Canyon. People who did not know each other before the trip seemed to come to the trip ready to act in a communitarian way. The guides facilitated the communion by developing rules for the trip, by encouraging group members to cast off goods that differentiated themselves in favor of shared goods, by putting all group members into a common uniform (wet suit, rain gear or life jacket), by asking for help in loading and unloading the boat and by encouraging the group to help paddle and to assist when others in the group needed help. The challenges of the water and the canyon also fostered bonding as the group worked together to achieve difficult but definable goals. Communion gradually deepened during the course of the trip and remained long afterward. One-third of respondents in a post-trip measure mentioned that interaction with others was one of the best things that happened on the trip. Post-trip measures also indicated that being with family and connecting with others on the trip helped participants to see life in a new perspective and to see what really mattered.

Frederickson and Anderson (1999) studied the wilderness experiences of two groups of women, one in the Boundary Water Canoe Area Wilderness and one in the Grand Canyon. Careful reading of participants' journals indicated that three of nine thematic codes developed to characterize the experience directly involved interactions and relationships among the group. Interviews indicated that being with an all-women's group was important to participants because it fostered group trust and emotional support, the sharing of common life changes and a noncompetitive atmosphere. This group cohesion, along with being in a bona fide wilderness, helped the women achieve spiritual inspiration, a benefit that we turn to in a later section.

Educational Benefits

The educational benefits of wilderness include nature learning, developing an environmental ethic and undertaking responsible environmental stewardship. Educational psychologists have identified a variety of kinds of learning, and several of these seem to be the possible result of leisure engagements: information (factual) learning, concept learning, schematic learning, metacognition

learning, direct visual memory, behavior change and skill learning and attitude and value learning (Roggenbuck and others 1991). The environmental education profession has developed principles on how best to educate environmentally: hands-on strategies, multidisciplinary approaches, higher-order thinking skills and developmental learning (Roggenbuck and Driver 1996). The best predictors of responsible environmental behavior and environmental activism are environmental sensitivity, respect for and knowledge about the environment, knowledge and skill at using environmental action strategies, high locus of control and feelings of personal responsibility toward the environment (Hines and others 1986; Sia and others 1985). Finally, environmental educators have discovered that environmental sensitivity is one of the best correlates of responsible environmental behavior (Roggenbuck and Driver 1996).

Marcinkowski (1989) suggests that such sensitivity appears to result from the interplay of outdoor experiences (usually at an early age), role models who are empathetic to the environment and knowledge about the natural environment. Chawla (1992) reports that children develop an empathetic connection with the environment through positive outdoor experiences over extended periods of time in natural places, either during solitary play or activities with friends or families.

These findings on kinds of environmental learning and how people learn about the environment suggest that wilderness and wilderness-like environments are excellent settings for nature learning and care. In addition, other authors claim that periodic visits to wilderness help us to recognize that we are plain citizens or at most stewards, not masters, of the land; help us gain long-sighted ecological and evolutionary wisdom; instill in us a reverence for life and a proper sense of beauty; and promote a sense of individual responsibility (Nelson 1998). In other words, wilderness visits are ideal for developing an environmental land ethic and environmental stewardship.

But is there any evidence that wilderness or wild places are uniquely suited for providing these benefits? While we certainly acknowledge that most people learn about nature and develop a responsible environmental ethic without ever setting foot in wilderness-like settings, there is some evidence that wilderness is a special learning laboratory. Large numbers of wilderness recreationists indicate that they seek out wild places in order to learn about nature (Driver and others 1987). Boy Scouts, Girl Scouts and other youth groups seek out and utilize wilderness or wilderness-like settings as classrooms to learn outdoor skills, wildlife lore and ecological relationships.

Participants in the Talbot and Kaplan (1986) Outdoor Challenge Program reported that learning was one of the best things about their time in wilderness. Over time in wilderness, they were increasingly able to notice and appreciate the details of nature, and they came away from the experience resolved to become more involved with nature. Commitment for continued involvement with nature was greatest among groups who stayed longer in wilderness.

Borrie (1995) measured desire to care for Okefenokee Wilderness among its visitors at multiple points in time during their wilderness stay. Care was very high at all times and increased as the stay in wilderness progressed.

Finally, environmental philosophers and activists often point to significant nature experiences, often singular events, where they felt an almost spiritual connection with the earth that shaped or sustained their love and commitment for nature (Tanner 1980). For Rachel Carson (1962), it was childhood explorations of the woods and fields around the family farm in the Allegheny Mountains. For Aldo Leopold, it was the encounter with the green eyes of a dying wolf in a Mexican wilderness and with cranes in a Wisconsin marsh (Leopold 1949). We believe that such epiphanies occur and shape the environmental connection, care and commitment among today's wilderness visitors, but we have little research on the nature, extent and implications of such deep experiences.

Spiritual Benefits

Nelson (1998) has suggested that, for some, wilderness is "a site for spiritual, mystical, or religious encounters; places to experience mystery, moral regeneration, spiritual revival, meaning, oneness, unity, wonder, awe, inspiration, or a sense of harmony with the rest of creation." This was certainly the case for John Muir. For him, the wilderness of Yosemite's Hetch Hetchy Valley was a shrine to a higher existence, whose destruction was tantamount to sacrilege. Transcendentalists such as Ralph Waldo Emerson, Thoreau and William Cullen Bryant went so far as to suggest that one could only understand moral and aesthetic truths in wilderness (Nelson 1998).

Do today's wilderness visitors seek and gain such spiritual outcomes? While little research has yet been done on nature/wilderness and the human spirit, interest in this topic has grown dramatically in the last decade. For example, Driver and others (1996) recently edited a well-received volume on the topic. Our own sense is that while a diversity of spiritual meanings are today assigned to wilderness-person transactions, and while many, if not most, are quite likely different from those described by Muir and Emerson, the spiritual benefits are among the most special and valued of all wilderness benefits.

Past measures of recreation experience preferences have typically placed the importance of spiritual outcomes as moderate to low relative to many other outcomes sought in wilderness. But we believe that the several-item "Spiritual" Recreation Experience Preference scale is too simple and global to capture the complexity and tremendous breadth of the human spirit-nature interaction. As a part of this complexity, spiritual experiences in wilderness frequently look outward, to an almost mystical breaking down of the boundaries between humans and nature, between humans and the cosmos. In these epiphanies, people feel an almost out-of-body connection with forces outside themselves and a sense of merging in time and space with earth's objects, creatures or processes. These feelings promote interacting senses of reverence, awe, elation, mystery, continuity and, at the same time, humility.

Sigurd Olson, wilderness philosopher and advocate, described one such spiritual experience in the his book *The Singing Wilderness* (1956):

> I once climbed a great ridge called Robinson Peak to watch the sunset and to get a view of the lakes and rivers below, the

> rugged hills and valleys of the Quetico-Superior. When I reached the bald knob of the peak the sun was just above the horizon, a flaming ball ready to drop into the dusk below....As I watched and listened, I became conscious of the slow, steady hum of millions of insects and through it the calling of the white-throats and the violin notes of the hermit thrushes. But it all seemed very vague from that height and very far away, and gradually they merged one with another, blending in a great enveloping softness of sound no louder, it seemed, than my breathing.
>
> The sun was trembling now on the edge of the ridge. It was alive, almost fluid and pulsating, and as I watched it sink I thought that I could feel the earth turning from it, actually feel its rotation. Overall was the silence of the wilderness, that sense of oneness which comes only when there are no distracting sights or sounds, when we listen with the inward ears and see with inward eyes, when we feel and are aware with our entire beings rather than our senses. I thought as I sat there of the ancient admonition, 'Be still and know that I am God,' and knew that without stillness there can be no knowing, without divorcement from outside influences man cannot know what spirit means.

Recent studies disclose these psychologically deep feelings about wilderness. Frederickson and Anderson (1999) reported that two groups of women, one in the Boundary Waters Canoe Area Wilderness and one in the Grand Canyon, had deeply spiritual experiences, experiences that in many ways were beyond the capability of words to describe. Their experiences had a certain ineffability and intangibility about them. Nevertheless, the women reported heightened sensory awareness and momentary loss of the passage of time. Feelings of empowerment, hopefulness, feeling grounded and secure, wonder and awe and humility accompanied the spiritual moments. Finally, self-reports by the women, both during and after the trip, indicated the wilderness environment was conducive to these experiences. More specifically, the women mentioned the impact of big, remote wilderness, the long periods of solitude and the inherent physical challenges as critical to their experiences.

Borrie (1995) also measured the spiritual benefits of the Okefenokee Wilderness visit by assessing feelings of humility during the experience. Respondents as a group felt moderate levels of humility, but this sense of awe and insignificance in nature increased dramatically as the trip unfolded.

In conclusion, we believe that the existence of the spiritual benefits and the preservation of natural ecosystems represent the two most important reasons for protecting designated wilderness.

Aesthetic and Creativity Benefits

Driver and others (1987) describe well the meanings and value of the aesthetic in the American wilderness context. Here we are talking about much more than grand scenery, although scenic enjoyment is a major motivator of wilderness visits. We are speaking of places of awe and the sublime, and such responses border on the mystical or religious discussed above; in fact, it is difficult to clearly differentiate between the spiritual and the aesthetic. Nash (1982) argues that the experience of wild things involves "awe in the face of large, unmodified natural forces and places—such as storms, waterfalls, mountains and deserts." Scenery that produces awe borders on the terrifying; even a man as self-confident as Henry David Thoreau experienced fear on the brooding slopes of Mount Katahdin in Maine (Torry and Allen 1949). But the awesome is inspirational, and it unleashed the creative forces of romantic writers and painters of the American wilderness. This literary genre transformed the awesome, the terrifying, to the sublime. And today, the sublime is beautiful, transcendent, a mirror of God and, most importantly, a continued source of inspiration for artists and intellectuals alike (Driver 1996).

Nature appreciation/enjoyment of nature remains consistently at the top of preferred experiences in wilderness (Driver and others 1987). The desire for opportunities for creativity is less often included on experience preference checklists, but when present, it usually has moderate importance.

Three of the studies frequently cited here provide direct evidence of the benefits of contact with awesome nature. Over 60% of the participants on the Talbot and Kaplan (1986) wilderness program cited awe and wonder about nature in their journals. Such encounters with nature were a special thrill and were hard to believe. One such encounter, seeing a bear, was described as incredible. Feelings of awe were described as sacred, mysterious and spiritual by more than half of the respondents.

Grand Canyon river runners remembered the river and the canyon long afterwards as stark but grand, as awesome (Arnould and Price 1993). This helped promote a communion with nature. Borrie's (1995) measure of humility assessed the level of felt awe as respondents canoed through the Okefenokee Swamp. While this area lacks grand scenery, it does brood. There, subjects felt only moderate levels of awe, but these feelings intensified as time passed in the swamp.

Other Benefits

While our focus has been on the personal benefits of nonfacilitated uses of wildness and almost entirely on the benefits realized by the on-site users, we would be remiss if we did not emphasize again that other types of benefits are very important. Of most importance is the apparently wide array of benefits realized by the off-site users we mentioned at the beginning of this paper. Quite unfortunately, we cannot quote more research results about those benefits, other than our earlier reference to the household surveys that identified many off-site supporters of wilderness protection and to the Cordell and others' study (1998). This is a vital area for much future research because we believe that, in aggregate, the benefits of wilderness to off-site users greatly exceed those of on-site users, simply because of many more off-site users.

We have mentioned only in passing the several studies documenting that existence of local natural and other amenities are important contributors to peoples' perceived satisfaction with the quality of their lives (see the "Quality of Life Benefits" section in the Driver and others' (1987) paper). In addition, many studies, including some in this volume, have documented the economic importance of nature-based tourism, including the recreational uses of wilderness, as very

important to many local communities for their economic stability and growth. This is especially true for communities that have become less dependent economically on the natural resource extractive industries.

Last, when defining the word "benefit" at the beginning of this paper, we emphasized that the first two types of benefit defined—an improved condition or maintenance of a desired condition—to the biophysical environment, as well as to individuals and groups of individuals. Certainly one of the most, if not the most, important benefit of wilderness is to improve and maintain the representative natural ecosystems that the NWPS was developed to protect.

Summary of Benefits

In summary then, much progress has been made on documenting the benefits of wilderness use since the Driver and others (1987) review. The evidence is strong for mental health/stress relief, skill development and nature appreciation values. Some related physical fitness research has been done, but we recommend more such research in wilderness. We believe there is much evidence for the personal development benefits of wilderness, but programmed, group-sponsored visits have been much more studied than nonfacilitated visits. Surprisingly, little research has been conducted on peak experiences, spiritual values, family bonding and group cohesion, and the self-sufficiency/primitive living benefits of wilderness or on the benefits realized by the off-site users. We recommend that the wilderness research profession give much more attention to these benefits.

Setting Dependencies of the Benefits

A central issue/question to the topic of this paper is: To what degree do the benefits attributed to wilderness in this paper actually depend or uniquely depend on a wilderness environment? Our answer, elaborated in Driver (1999), has three parts. The first part, as we discussed and referenced in our section on Social Identity Benefits, is the evidence that the influence of the social setting on perceived experiences and meanings frequently override the influence of the biophysical settings. The second part relates to the fact that when each satisfying psychological experience/perceived benefit is taken individually, it is difficult to support the claim of unique dependency for any of the benefits discussed; we reiterate that we are saying this when each benefit is considered by itself. Each of the experiences/perceived benefits discussed can be individually realized in nonwilderness and, frequently, in nonnatural settings.

However, much research, including that reviewed here, has shown that recreationists do not engage in a particular activity or set of activities in selected environments to realize only one type of satisfying experience. Instead, there is a bundle of experiences that are highly valued for a particular outing. Thus, there is an experience gestalt made up of that package or bundle of several separate satisfying psychological outcomes, such as nature appreciation or spiritual renewal. This bundle varies somewhat from recreation activity to activity and somewhat from user to user. We would guess that satisfaction realized from this total package is greater than the sum of satisfactions realized from each individual experience in the package; as with most gestalts, the whole is greater than the sum of the parts. The punch line is that we believe that these experience gestalts are highly dependent on particular recreation settings, including wilderness settings. But much complex research is needed to test this hypothesis.

The third part of our answer about setting dependencies of the experiences/benefits is that in a pluralistic republic, it really does not matter too much if setting dependency exists. Obviously, many people have shown by their revealed preferences/behaviors that they prefer to realize certain experiences/benefits in wilderness settings, just as each of us reveals preferences for different types of automobiles, food, clothing, books, TV programs and so on. In a representative democracy guided by reasonable voter and consumer sovereignty, we should be able to exercise our preferences so long as we have a willingness to pay—by price and/or taxation—for the goods and service we prefer. This obviously becomes complicated if others with greater willingnesses to pay demand that the facilitating wilderness resources be used for alternative purposes. That is what the political process is about--the allocation of scarce resources among completing values. But we emphasize that valid and reliable information about the recreational benefits of wilderness is very important in the political arena. Put simply, if enough people demand wilderness preservation and protection for its many benefits, including the recreational ones, political activity will continue to protect wilderness as it has in the past.

Developments in Describing and Measuring Wilderness Benefits in the 1990s

As noted in our introduction, there have been two advances in the 1990s regarding benefits research: developing a deeper understanding of the nature of the total experience of recreation and re-creation, and the development of a framework for benefits-informed management. We now briefly review some of the key tenets of the total experience approach, how recent benefit studies that we have cited have begun to measure experiences more holistically and how this approach has increased our understanding of benefits.

Key Tenets of the Total Experience Approach

Experience as Emergent

By emergent, we mean that experience evolves, most typically across time. Thus, the total experience cannot be fully measured at any one point in time. Many of the benefit studies reviewed here meet this requirement. Some recognize the multi-phasic nature of leisure experiences. While only the Arnould and Price (1993) study of "river magic" on the Grand Canyon rafting trips contained measures of the anticipation phase of the experience, many others combined both on-site and post-trip recollection measures. For

example, Arnould and Price (1993) had participant observation and interviews on-site and mail-back surveys and focus group discussions after the trip to better understand the emerging experience. Frederickson and Anderson (1999) used journals to understand women's experiences in wilderness and in-depth personal interviews three weeks after the trip to understand the permanency and strength of powerful spiritual experiences in wilderness. Walker and others (1998) measured experiences received on-site and recollected off-site benefits about three weeks later.

Several of the studies also measured the emerging experience at several points in time and in space during the on-site experience. For example, Frederickson and Anderson (1999) and Talbot and Kaplan (1986) used journals to obtain almost daily accounts of the unfolding experience. Participant observers measured critical aspects of the river magic trip throughout the entire stay in the canyon.

Borrie (1995) and McIntyre (1998) used the experience sampling method to obtain multiple measures of respondents' focus of attention and feelings of wilderness at random points in time throughout their stay in wilderness. Through these means, the researchers were able to learn how the experience ebbed and flowed in real time.

Experience as States of Mind

The emphasis here is on states of mind (Stewart 1998). Several of the studies of experiences cited in our review recognize that leisure experiences are complex, and they measure more than one of the cognitive, affective and behavioral dimensions of leisure. For example, while studies of the learning benefits of recreational engagements tended to focus on cognitions, many also measured a "sense of wonder." Borrie (1995) and McIntyre (1998) not only measured feelings about wilderness with real time measures, they also measured focus of attention at the same moment. McIntyre went further to identify what the respondent was doing at the moment. This begins to permit a much richer analysis of the person-environment transaction.

The work on benefits by the Kaplans, Ulrich and his colleagues and Hartig and his associates measured multiple aspects of nature experiences and related them to multiple behavioral and physiological measures of health, with the Kaplans tending to emphasize cognitive response and Ulrich stressing interacting physiological and affective responses. These two different theoretical approaches not only help us understand health benefits, they also permit us to understand how people process stimuli from the natural environment.

Experience as Transactions

We believe that the view of a leisure experience as transactions needs more emphasis. This really not novel view sees the individual as an active player in negotiating his or her transaction with the environment. This has two important implications for understanding recreational experiences and benefits. The transaction becomes the unit of analysis of interest, more so than the person or the environment. And analysis and reporting of experiences become much more idiosyncratic, or presumably much more variable across individuals in a leisure setting. Such an approach presumably suggests much more variability in benefits attained. While we see increased lip service given to the advantages of viewing the experience in wilderness from a transactional perspective, few of the studies that we reviewed actually focused on these transactions. Fewer still have fully operationalized this perspective in any meaningful way.

There certainly has been a move to focus on the individual in reporting and describing experiences. The Arnould and Price (1993) study of river magic and the Frederickson and Anderson (1999) study of spiritual values represent examples. This focus has the advantage of describing experiences in a deep and rich manner; it has the disadvantage of not being generalizable across a population. The Patterson and others' study (1998) has elements of a transactional perspective, and to that we now turn.

Experience as Story

This view of leisure rests on the assumptions of experience as emergent and experience as transaction. Because human experience is mutually defined by transactional relationships among settings, individuals with unique identities and situational influences, humans are in some measure free to create their own meaning of their experiences (Patterson and others 1998). They do this, in part, by creating stories of their experience.

The Patterson and others' study of Juniper Prairie Wilderness canoeists represents an example of experience as story or narrative. It rests on the notion of situated freedom-that is, the notion that there is structure in the environment which sets boundaries of what can be perceived or experienced, but that within those boundaries, recreationists are free to express the world in highly individual, unique and variable ways. For example, while Patterson and his coauthors found challenge a pervasive experience dimension among canoeists, they also found that their respondents defined the meaning of challenge quite differently. Some saw challenge as the defining characteristic of the experience, some said challenge defined the meaning of the experience, some saw challenge as creating a good story, and others were ambivalent about challenge. Within the categories of challenge as defining characteristic or as story, some felt negative about challenge and others felt positive. In addition, meaning could and did appear to change across time, confirming that experiences are emergent not only because of evolving transactions with the environment on-site, but also based on situational circumstances across time.

Implications of the Total Experience Paradigm for Benefits

The total experience paradigm implies:

- The environment-experience-benefit linkages are very complex, probably more complex than previously thought.
- The environment sets broad parameters within which the nature and intensity of experiences and benefits are constituted. There is a need to better understand these parameters.

- Experiences as they are preferred, expected, and lived, and as they relate to subsequent improved or maintained conditions, can be described at varying levels of specificity. Planners, managers and researchers must decide on the level of analysis most useful for their purposes.
- Experiences and benefits ebb and flow during the multiple phases of recreational engagement.
- Experiences and benefits likely ebb and flow during on-site engagements.
- There is a need to know how the ebb and flow of experience satisfaction during phases of the recreational engagement relate to overall satisfaction and benefits.
- There is a need to understand the process that creates narratives to assign meaning to experiences of nature and how narratives shape benefits. Experiences as they are preferred, expected, and lived, and as they relate to subsequent improved or maintained conditions, can be described at varying levels of specificity. Planners, managers and researchers must decide on the level of analysis that is most useful for their purposes.

The second author offers a precautionary note about this last implication. He clearly recognizes that the total experience approach will contribute greatly to advancement of leisure theory-that is, to our understanding of recreation motivations, preferences and behavior. Nevertheless, he wonders how the diversity of values, meanings, preferences, reflections and behaviors disclosed can be integrated usefully into the management of recreation, park and other amenity resources. As scientists, we will lose much support if we fail to address and answer that question. Yes, we must advance theory, but that is not enough.

We view the "total experience" paradigm as a supplement or complement to research that has used instruments such as the Recreation Experience Preference (REP) scales. We need different methods, including physiological measures, to define and quantify the benefits in the most valid and reliable ways we can. We disagree with those (for example, Stewart 1998) who have suggested that the large body of research on recreation experiences reviewed here, which provides much of the empirical support for benefits-informed management, has slowed efforts to gain a deeper understanding of recreation experiences. We don't think this is the case, for two reasons. First, there has been relatively little use of the Recreation Experience Preference (REP) scales reported in the research literature since 1985. During the same period, much progress, as we have reported here, has been made. Second, the conceptual framework within which those scales are housed explicitly includes the concept of a recreation experience continuum and acknowledges that human behavior and responses are dynamic (see Driver and Tocher 1970). Therefore, the theory fully accommodates and supports the "total experience" perspective. For these two reasons, one should look elsewhere (beyond use of REP scales) for explanations of why the total experience framework has not been adopted more widely.

And we should not forget the great contributions that results of the REP scales have made in changing professional mindsets toward more seriously considering visitors' wants and preferences and in providing the base for most of the outdoor recreation and other amenity resource management systems now being used by land management agencies in the United States and other countries. To reiterate, we are not advocating a one-and-only approach to quantifying recreation experiences; instead, we suggest wider use of the total experience approach, which we think will supplement and add to the results found from the other approaches.

Managing for Benefits

We end this paper with a brief discussion of why wilderness areas should be managed overtly to provide opportunities for the realization of benefits explicitly targeted for provision by managers. To our way of thinking, the only reason that any public lands, including publicly administered wilderness areas, are managed is to provide benefits and prevent disbenefits, whether to humans or to the biophysical environment. Put differently, the fundamental purpose of management is to create positive outcomes and minimize negative outcomes. Within that framework, it is our position that managers know what they are doing to the extent that they understand what the desired positive and undesired negative outcomes are, as well as how well they know how to optimize opportunities for the realization of net benefits. Just as medical doctors must understand how they can positively and negatively impact their patients, managers of wilderness must have the same degree of understanding; as noted, those impacts can accrue to humans or to the biophysical environment.

Elsewhere, this approach to management has been called benefits-based management and, more recently, outcomes-focused management to explicitly cover the need to address negative outcomes (Driver 1999, Driver and Bruns 1999). These other papers explain the concept of outcome-focused management, and the interested reader can easily interpret how that approach can be applied to management of wilderness resources. We believe that such application is necessary and that we now know enough about the many benefits of wilderness to implement it.

References

Arnould, E.J.; Price, L.L. 1993. River magic: extraordinary experience and the extended service encounter. Journal of Consumer Research. 20: 24-45.

Borrie, W.T. 1995. Measuring the multiple, deep, and unfolding aspects of the wilderness experience using the experience sampling method. Blacksburg, VA: Virginia Tech, Dept. of Forestry. Ph.D. dissertation. 266 p.

Borrie, W.T.; Roggenbuck, J.W. 1996. Describing the wilderness experience at Juniper Prairie Wilderness using experience sampling methods. In: Rulhavy, D.L.; Legg, M.H., eds. Wilderness and natural areas in eastern North America: problems, management, and planning. Nacogdoches, TX: Stephen F. Austin State Univ.: 165-172.

Bunting, C.J.; Little, J.J.; Tolson, H.; Jessup, G. 1986. Physical fitness and eustress in the adventure activities of rock climbing and rappelling. Journal of Sports Medicine and Physical Fitness. 26: 11-20.

Callicott, J.B.; Nelson, M.P., eds. 1998. The great new wilderness debate. Athens, GA: The University of Georgia Press. 697 p.

Carson, R. 1962. Silent spring. Boston, MA: Houghton Mifflin Co.

Chawla, L. 1992. Research priorities in environmental education. Children's Environments. 9(1): 68-71.

Cimprich, B. 1992. Attentional fatigue following breast cancer. Research in Nursing and Health. 15: 199-207.

Cimprich, B. 1993. Development of an intervention to restore attention in cancer patients. Cancer Nursing. 16: 83-92.

Clawson, M.: Knetsch, J.L. 1966. Economics of outdoor recreation. Baltimore, MD: John Hopkins Press.
Cole, D.N. 1996. Wilderness recreation use trends, 1965 through 1994. Ogden, UT: U.S. Department of Agriculture. Forest Service. Intermountain Forest and Range Experiment Station. 11 p.
Cordell, K.: Tarrant, M.; McDonald, B.; Bergstrom. 1998. How the public views wilderness: More results from the USA survey on recreation and the environment. International Journal of Wilderness. 4(3): 28-31.
Cronon, W. 1995. The trouble with wilderness, or, getting back to the wrong nature. In:Cronon, W., ed. Uncommon ground: toward reinventing nature. New York: W.W. Norton: 69-70.
Csikszentmihalyi, M. 1990. Flow: the psychology of optimal experience. New York: Harper and Row Publishers, Inc.
Csikszentmihalyi, M; Kleiber, D.A. 1991. Leisure and self-actualization. In: Driver, B.L.; Brown, P.J.; Peterson, G.L., eds. Benefits of leisure. State College, PA: Venture Publishing, Inc.: 91-102.
Driver, B.L.; Bruns, D. 1999. Concepts and uses of the Benefits Approach to Leisure. In: Jackson, E.L.; Burton, T.L., eds. Leisure studies: prospects for the twenty-first century. State College, PA: Venture Publishing, Inc.: 349-368.
Driver, B.L. 1999. Management of public outdoor recreation and related amenity resources for the benefits they provide. In: Cordell, H.K. and others. Outdoor recreation in American life: a national assessment and demand and supply trends. Champaign, IL: Sagamore Publishing: 2-5 and 27-29.
Driver, B.L.; Brown, P.J.; Peterson, G.L. 1991. Benefits of leisure. State College, PA: Venture Publishing, Inc.
Driver, B.L., Dustin, D.; Baltic, T.; Elsner, G.; Peterson, G.. 1996. Nature and the Human Spirit: Toward An Expanded Land Management Ethic. State College, PA: Venture Publishing, Inc. 467 p.
Driver, B.L.; Nash, R.; Haas, G. 1987. Wilderness benefits: a state-of-knowledge review. In:Lucas, R.C., compiler. Proceedings—national wilderness research conference: issues, state-of-knowledge, future directions; 1985. July 23-26, Fort Collins, CO. Ogden, UT: U.S. Department of Agriculture. Forest Service. Intermountain Forest and Range Experiment Station: 294-319.
Driver, B.L.; Tinsley, H.E.A.; Manfredo, M.J. 1991. The paragraphs about leisure and recreation experience preference scales: Results of two inventories designed to assess the breadth of the perceived psychological benefits. In: Driver, B.L.; Brown, P.J.; Peterson, G.L., eds. 1991. Benefits of leisure. State College, PA: Venture Publishing, Inc.: 263-286.
Driver, B.L.; Tocher, S.R. 1970. Toward a behavioral interpretation of recreational engagements, with implications for planning. In: Driver, B.L., ed. Elements of outdoor recreation. Ann Arbor, MI: The University of Michigan Press: 9-31.
Driver, S. 1996. Values of nature for artists and artists' interpretation of those values for society. In: Driver, B.L.; Dustin, D.; Baltic, T.; Elsner, G.; Peterson, G., eds. Nature and the human spirit: toward an expanded land management ethic. State College, PA: Venture Publishing, Inc.: 185-191.
Ewert, A. 1985. Why people climb: the relationship of participant motives and experience level to mountaineering. Journal of Leisure Research. 17(3): 241-250.
Ewert, A. 1993. Differences in the level of motive importance based on trip outcome, experience level and group type. Journal of Leisure Research. 25(4): 335-349.
Ewert, A.W. 1994. Playing the edge: motivation and risk taking in a high-altitude wilderness-like environment. Environment and Behavior. 26(1): 3-24.
Frederickson, L.A.; Anderson, D.H. 1999. A qualitative exploration of the wilderness experience as a source of spiritual inspiration. Journal of Environmental Psychology. 19: 21-39.
Hartig, T.; Mang, M.; Evans. G.W. 1991. Restorative effects of natural environment experiences. Environment and Behavior. 23(1): 3-26.
Heywood, J.L. 1987. Experience preferences of participants in different types of river recreation groups. Journal of Leisure Research. 19(1): 1-12.
Heywood, J.L. 1990. Collective social groups in the wilderness: problems and prospects. In: Easley, A.T.; Passineau, J.F.; Driver, B.L., compilers. The use of wilderness for personal growth, therapy, and education. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. Gen. Tech. Rep. RM-193: 64-69.
Hines, J.M.; Hungerford, H.R.; Tomera, A.N. 1986-87. Analysis and synthesis of research on responsible environmental behavior: a meta-analysis. The Journal of Environmental Education. 18(2): 1-8.
Kaplan, R.; Kaplan, S. 1989. The experience of nature: a psychological perspective. New York: John Wiley & Sons. 340 p.
Kaplan, S. 1995. The restorative benefits of nature: toward an integrative framework. Journal of Environmental Psychology. 15: 169-182.
Katcher, A.H.; Segal, H.; Beck, A. 1984. Comparison of contemplation and hypnosis for the reduction of anxiety and discomfort during dental surgery. American Journal of Clinical Hypnosis. 27: 14-21.
Leopold. A. 1949. A Sand County almanac and sketches here and there. New York: Oxford University Press. 226 p.
Manfredo, M.J.; Driver, B.L.; Tarrant, M.A. 1997. Measuring leisure motivation: a meta-analysis of recreation experience preference scales. Journal of Leisure Research. 28(3): 188-213.
Mannel, R. 1996. Approaches in the social and behavioral sciences to the systematic study of hard-to-define human values and experiences. In: Driver, B.L.; Dustin, D.; Baltic, T.; Elsner, G.; Peterson, G., eds. Nature and the human spirit: toward an expanded land management ethic. State College, PA: Venture Publishing: 405-416.
Marcinkowski, T.J. 1988. An analysis of correlates and predictors of responsible environmental behavior. Carbondale, IL: Southern Illinois Univ. Ph.D. dissertation. 749 p.
Marans, R.W.; Mohai, P. 1991. Leisure resources, recreation activity, and the quality of life. In: Driver, B.L.; Brown, P.J.; Peterson, G.L., eds. 1991. Benefits of leisure. State College, PA: Venture Publishing, Inc.: 351-363.
Maslow, A. 1968. Toward a psychology of being. New York, NY: Van Nostrand Reinhold.
McIntyre, N. 1998. Person and environment transactions during brief wilderness trips: an exploration. In: Watson, A.E.; Aplet, C.H.; Hendee, J.C., compilers. Personal, societal, and ecological values of wilderness: Sixth World Wilderness Congress proceedings on research, management, and allocation, volume 1: 1997; October; Bangalore, India. Proc. RMRS-P-4. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 79-84.
Montes, S. 1996. Uses of natural settings to promote, maintain, and restore human health. In: Driver, B.L.; Dustin, D.; Baltic, T.; Elsner, G.; Peterson, G., eds. Nature and the human spirit: toward an expanded land management ethic. State College, PA: Venture Publishing, In.: 105-118.
Moore, E.O. 1982. A prison environment's effect on health care service demands. Journal of Environmental Systems. 11: 17-34.
Nash, R. 1982. Wilderness and the American mind. 3rd ed. New Haven, CT: Yale University Press.
Nelson, M.P. 1998. An amalgamation of wilderness preservation arguments. In: Callicott, J.B.; Nelson, M.P., ed. The great new wilderness debate. Athens, GA: The University of Georgia Press: 154-198.
Olson, S. 1956. The singing wilderness. New York, NY: Knopf.
Olson, S.F. 1938. Why wilderness? American Forests. 100(11/12): 49-53.
Orthner, D.K.; Mancini, J.A. 1991. Benefits of leisure for family bonding. In: Driver, B.L.; Brown, P.J.; Peterson, G.L., ed. Benefits of leisure. State College, PA: Venture Publishing Co.: 289-302.
Paffenbarger, Jr., R.S.; Hyde, R.T.; Dow, A. 1991. Health benefits of physical activity. In: Driver, B.L.; Brown, P.J.; Peterson, G.L., eds. Benefits of leisure. State College, PA: Venture Publishing, Inc.: 49-58.
Patterson, M.E.; Williams, D.R.; Watson, A.E.; Roggenbuck, J.W. 1998. An hermeneutic approach to studying the nature of wilderness experiences. Journal of Leisure Research. 3(4): 423-452.

Quarrick, G. 1989. Our sweetest hours: recreation and the mental state of absorption. Jefferson, NC: McFarland.

Roggenbuck, J.W.; Driver, B.L. 1996. Public land management agencies, environmental education, and an expanded land management ethic. In: Driver, B.L.; Dustin, D.; Baltic, T.; Elsner, G.; Peterson, G., eds. Nature and the human spirit: toward an expanded land management ethic. State College, PA: Venture Publishing, Inc.: 383-404.

Roggenbuck, J.W.; Loomis, R.J.; Dagostino, J.V. 1991. The learning benefits of leisure. In: Driver, B.L.; Brown, P.J.; Peterson, G.L., eds. Benefits of leisure. State College, PA: Venture Publishing, Inc.: 195-214.

Sax, J.L. 1980. Mountains without handrails. Reflections on the national parks. Ann Arbor, MI: The University of Michigan Press.

Scherl, L. 1990. The wilderness experience: A psychological evaluation of its components and dynamics. In: Easley, A.T.; Possineau, J.F.; Driver, B.L., compilers. The use of wilderness for personal growth, therapy, and education. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. Gen. Tech. Rep. RM-193:11-22.

Sia, A.; Hungerford, H.; Tomera, A. 1985-86. Selected predictions of responsible environmental behavior: an analysis. The Journal of Environmental Education. 17(2): 31-40.

Stein, T.V.; Lee, M.E. 1995. Managing recreation resources for positive outcomes: an application of benefits-based management. Journal of Park and Recreation. 13(3): 52-70.

Stewart, W.P. 1998. Leisure as multiphase experiences: challenging traditions. Journal of Leisure Research. 30(4): 391-400.

Talbot, J.F.; Kaplan, S. 1986. Perspectives on wilderness: re-examining the value of extended wilderness experiences. Journal of Environmental Psychology. 6: 177-188.

Tanner, T. 1980. Significant life experiences: a new research area in environmental education. Journal of Environmental Education. 11(4): 20-24.

Torry, B.; Allen, F.E., eds. 1949. The journal of Henry David Thoreau. 14 vols. Walden edition. Boston, MA: Houghton Mifflin.

Ulrich, R.S. 1984. View through a window may influence recovery from surgery. Science. 244: 420-421.

Ulrich, R.S.; Dimberg, U.; Driver, B.L. 1991a. Physiological indicators of leisure benefits. In: Driver, B.L.; Brown, P.J.; Peterson, G.L., eds. Benefits of leisure. State College, PA: Venture Publishing Co.: 73-89.

Ulrich, R.S.; Simons, R.F. 1986. Recovery from stress during exposure to everyday outdoor environments. In: Wineman, J.; Barnes, R.; Zimring, C., eds. Proceedings of the Seventeenth Annual Conference of the Environmental Design Research Association; 1986; April. Atlanta, Washington, DC: EDRA: 115-122.

Ulrich, R.S.; Simons, R.F.; Losito, B.D.; Fiorito, E.; Miles, M.A.; Zelson, J. 1991b. Stress recovery during exposure to natural and urban environments. Journal of Environmental Psychology. 11: 201-230.

Virden, R.J.; Knopf, R.C. 1989. Activities, experiences, and environmental settings: a case study of recreation opportunity spectrum relationships. Leisure Sciences. 11: 159-176.

Walker, G.J.; Hull IV, R.B.; Roggenbuck, J.W. 1998. On-site optimal experiences and their relationship to off-site benefits. Journal of Leisure Research. 39(4): 453-471.

West, J.J. 1986. Landscape views and stress response in the prison environment. Seattle: University of Washington, Dept. of Landscape Architecture. M.L.A. thesis. 125 p.

Williams, D.R.; Haggard, L.M.; Schreyer, R. 1988. The role of wilderness in human development. In: Freilich, H.R., ed. Wilderness benchmark 1988: proceedings of the national wilderness colloquium; 1988. January 13-14; Tampa, FL. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. Gen. Tech. Rep. SE-51: 169-180.

Young, R.; Crandall, R.1986. Self-actualization and wilderness use: a panel study. In: Lucas, R.C., compiler. Proceedings—national wilderness research conference: current research; 1985; July 23-26; Fort Collins, CO. Gen. Tech. Rep. INT-212. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 385-388.

The Evolution of Wilderness Wildlife Research in North America

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Abstract—Most wildlife research in North America has focused on a standard suite of questions, asked of a limited assemblage of economically important species and studied using a relatively limited set of techniques, study site characteristics and narrow time-frames. We describe why these factors are not necessarily conducive to conducting wildlife research in wilderness settings. As a consequence, the amount of wildlife research conducted in wilderness settings has historically been small and limited primarily to wilderness-dependent species. We further describe the reasons for this, recent trends and the types of wildlife research questions that can best be addressed in wilderness settings.

Humans, as we define the species, have lived in intimate association with other animals for at least the past 200,000 years, serving as both predator and prey. For all but a small part of this time, they lived in what contemporary terms would call a wilderness environment. The constant interactions with animals, as predators and prey, forced the human species to become knowledgeable about attributes of animal biology and behavior. Knowledge was accumulated and passed down to succeeding generations. Learning the habits of the large game animals and carnivores was probably a true trial and error process. Natural selection played an important role since the trials were often life-threatening and the errors often fatal (Shepard 1973).

Human knowledge of animal behavior and the efficiency of methods to harvest wild animals continued to increase with the size of human populations. As a result, by the dawn of what is usually recognized as civilized culture—ca 5,000 - 7,000 years ago in southern Europe and the Mideast but much later in North America—many of the larger game species had been driven to extinction or were greatly diminished in abundance (Fagan 1989). When and where this occurred, human populations were forced to cease their nomadic ways and develop an agricultural lifestyle that relied on crops and recently domesticated animals. With this shift in lifestyle, the first permanent communities appeared (Gray 1993). As a consequence, the "wilderness quality" of the living environment diminished.

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One consequence of permanent settlement in ever larger communities was that innate knowledge of the ways of wild animals - essential for human survival over the eons but never recorded - became less important and was gradually lost (Shepard 1973). The more civilized Western society became, the more isolated the average person was from wild animals; by the 1600s, western European urban populations had little chance of encountering wild animals, and they could no longer be assured of even eating meat from any source.

With the later gradual evolution of a privileged/leisure class in society in the 18th and 19th centuries, interest in the natural history and taxonomic classification of wild animals increased. This interest was spawned in part by the global expeditions of explorers which awakened the Western world to the diversity of life on the planet (Borland 1975).

The Evolution of Wildlife Research in North America

Despite the long history of human involvement with wildlife, it was still not until the early 1900s that an interest in the *actual study* of wildlife began to blossom in North America. The American Game Protective and Propagation Association, a group largely made up of sportsmen, conservationists and sporting arms industry representatives that supported the conservation of game through laws and breeding programs, was instrumental in this effort (Greeley 1931). Initial studies were largely descriptive, based primarily on experience or opinion, lacking data and facts and essentially weak in scientific rigor. This was largely because investigations into the habits of wild animals were typically motivated and supported by various special interest groups. For example, state game departments were primarily interested in satisfying the demands of those who paid for hunting licenses, while universities and federal departments focused on the problems of poultry and livestock to the exclusion of wild bird and animals (Allen 1932).

However, through the discussions and papers presented at the annual American Game Conferences in the early 1900s and continuing in 1936 with its successor, the North American Wildlife Conference, the character of wildlife studies slowly began to change. Although revolutionary at the time, the idea that scientific research was important and could enhance the management of wildlife slowly became accepted and was formally adopted in the American Game Policy of 1930 (Leopold 1930). Beginning in 1935, Cooperative Wildlife Research Units were established at U.S. land grant universities to educate wildlife biologists, conduct research and better integrate state, federal and university

research programs. Enactment of the Federal Aid to Wildlife Restoration Act of 1937 provided the first legal recognition that wildlife management research was necessary and desirable.

Since the 1930s, research on wild animals, principally game animals, in North America has increased tremendously. Consequently, over the past half-century, scientists have learned a great deal about the biology, behavior and ecology of many species. There have been substantial changes and improvements during this time in the methods and analyses wildlife researchers have employed in their attempt to describe the biological characteristics of a given species.

However, there is much we do not know. This has led to speculation about the kinds of species that have been studied and where. We hypothesized that most studies have been conducted on species that are relatively common, have an economic importance either as game or for fur, or pose economic impacts because of damage to agricultural crops, depredation, or disease. We also hypothesized that the common study site is generally convenient, easily accessible by motorized vehicle, and amenable to the use of a variety of equipment and methods. We were also interested in the kinds of questions that biologists have typically asked about wildlife and about what factors have structured those questions. We suspected that over the history of contemporary wildlife research, biologists have asked a relatively limited suite of questions about wildlife, and that the same questions have been asked about the same species over and over again, varying only in the specific location/habitat of the particular study. For example, there have been 634 studies of white-tailed deer conducted in the U. S. and published in the *Journal of Wildlife Management* over the past 60 years, many asking the same questions and differing only in the location of the study.

Finally we suspected that the techniques and methods used to answer these questions, and the kinds of species that are typically involved, have resulted, we believe, in a relatively standard type of research design and that this design could have a strong influence on whether or not wilderness areas are selected for a specific research project. We therefore undertook a series of analyses to categorize the kinds of species studied, the research questions asked, and the research design used.

An Analysis of the Role of Wilderness Areas in Wildlife Research

We examined the role of wilderness areas in the scientific study of wildlife by analyzing the kinds of wildlife species studied over time, the type of environment where study was conducted, that is, in disturbed or human manipulated versus wilderness settings, and where possible, the spatial extent of the study sites. We also sought to characterize the questions or hypotheses the research addressed. In addition, we used the results of a survey by Pelton and Van Manen (1996) that summarized the duration of wildlife studies. (Note: In this paper, we use the term wilderness to refer to large, undisturbed natural areas—"wilderness" with the small "w" as in Schoenfeld and Hendee (1978)—rather than limit it exclusively to legally designated areas).

Methods Used in the Analysis

We defined wildlife broadly, in conducting this analysis, including all terrestrial mammal and avian species native to North America. We used articles published in the *Journal of Wildlife Management* (published from 1937 to the present) the *Wildlife Society Bulletin* (published from 1973 to the present) and *Conservation Biology* (published from 1987 to the present) to document the research studies that have taken place on the various species. We arbitrarily divided the research record into five year increments (with the exception of the first segment), starting in 1937 and continuing to the present, resulting in 13 time periods. For each time period, we examined and categorized every entry in the journals. We limited our analysis to articles that pertained to species of wildlife, eliminating articles that pertained to habitat improvement, analytical techniques and policy. In doing so, we utilized an overall average of 85% of articles published in each of the time periods in the wildlife journals and 7% of the articles published in each time period in *Conservation Biology*.

We grouped species into eight categories, based in part on ecological function, appearance, habitat requirements and human use, recognizing that any subdivision of this sort is arbitrary. These categories and the most common species included are listed at the bottom of table 1. We evaluated each study as to whether it took place in or out of a wilderness environment and attempted to determine the size of the study area. The former evaluation was often subjective because of the lack of a definitive site description. We tried to be conservative and, when in doubt, allocated a study to the wilderness category, when in actuality it may not have taken place in a wilderness environment. Finally, we characterized the primary research questions addressed in each of the studies.

To test for significant trends from 1937 to the present, we evaluated the proportion of studies in five-year increments using multiple regression (Zar 1996). Significance level was set at a=.05.

Assumptions Made in the Analysis

The *Journal of Wildlife Management* and its sibling publication, *The Wildlife Society Bulletin*, are the oldest refereed forums that report on North American wildlife issues. We assumed that these publications represented a valid sample of wildlife research in North America. To evaluate the thoroughness of the coverage of the subject matter encompassed by these journals, we examined the citations of all refereed journals contained in a college textbook on the history of wildlife management in North American (Peek 1986). We found that 49.7% of all journal citations contained in this book are from these two sources alone, and the remaining 50.3% are scattered among 42 different journals. In order to include the growing research emphasis in the field of conservation biology, we also surveyed all articles in

Table 1—Proportion of studies devoted to various mammal and bird species groups published in the *Journal of Wildlife Management* and the *Wildlife Society Bulletin* at five-year intervals between 1937 and 1996, and *Conservation Biology* between 1987 and 1996.

Category	1937	1941	1946	1951	1956	1961	1966	1971	1976	1981	1986	1991	1996
Game birds[1]	38	21	28	28	35	34	21	16	17	14	10	8	10
Waterfowl[2]	19	8	11	17	24	12	21	20	25	21	20	16	21
Songbirds and woodpeckers[3]	4	3	8	2	1	3	-	3	5	5	13	11	13
Raptors, owls and wading birds[4]	-	-	-	-	-	-	-	-	-	7	6	15	11
Large herbivores[5]	11	29	13	24	21	18	35	37	31	30	28	30	23
Small & medium sized mammals[6]	27	39	40	26	17	29	22	17	17	12	15	11	11
Bears[7]	-	-	-	-	-	2	2	4	2	5	3	3	5
Carnivores[8]	-	-	-	2	1	2	-	1	3	4	6	6	10
Number of studies analyzed	26	38	47	46	66	59	105	101	145	182	192	163	171

([1]pheasant, quail sp., grouse sp., woodcock, dove; [2]many different species with mallard and geese dominant; [3]red-cockaded woodpecker dominant; [4]bald eagle dominant; [5]white-tailed deer, mule deer, black-tailed deer, moose, pronghorn antelope, caribou, mountain sheep, bison, mountain goat, elk; [6]muskrat, cottontail rabbit, squirrel sp., coyote, raccoon, fox sp., beaver; [7]grizzly, black and polar bears; [8]wolf, mountain lion, bobcat, lynx)

the identified time periods in the journal *Conservation Biology*. We also examined all articles published from 1951 to the present in the *Journal of Mammalogy*, and the *Canadian Journal of Zoology*, We concluded that the majority of the research reported in these journals was more laboratory oriented and was not appropriate for this study.

We recognize that many studies, such as those conducted by scientists in areas like national parks, are never published in the refereed literature (Wright 1990). However, in most cases, evaluation has shown that these efforts do not constitute a true "research" study, but are rather simple surveys or monitoring efforts (Wright 1990).

Results of the Analysis

The proportion of studies devoted to the eight categories of animals is shown in table 1, grouped in five-year increments. The analysis included a total of 1,343 studies. For the first 30 years of the period analyzed (1937-1966), studies of game birds - particularly quail species and pheasant - were quite common, as were studies of medium-sized mammal species such as muskrat and cottontail rabbit. The number of studies in both of these categories declined appreciably over the next 30 years (1967-1996) as the research focus and probably funding appeared to change. Over the next 30 years, studies of breeding birds, such as the red-cockaded woodpecker in forested environments, and of habitat use by bear and carnivores increased. Studies of waterfowl and large herbivores were relatively constant over the entire time period, and no trend in changes in species composition was detectable over the time period.

We found no significant trend or change in the proportion of studies performed on large herbivores and waterfowl. A significant decrease in the proportion of studies for small mammals (p=.0003) and gamebirds (p=.0003) was noted. A significant increase in the proportion of studies for carnivores (p=.0002), bears (p=.0001) and songbirds (p=.0037) was found by using multiple regression analysis.

The proportion of all studies in each time period considered done in a wilderness environment are shown in table 2. The results suggest that there has been limited use of wilderness settings for wildlife research. This was particularly true in the first 30 years of the record. Over the past 30 years, as the data illustrate, there has been a gradual increase in the use of wilderness settings for wildlife research. Most of this has been on what we define below as wilderness-dependent species.

There is a great diversity in the types of wildlife projects reported in the journals that were surveyed. Approximately 25% of the publications analyzed over the time period were what we considered to be traditional field studies on a defined land area(s). Our determination of the spatial extent of these study sites was subjective because the sizes of the study areas and/or plots were not reported in many cases. We determined that about 18% of the field studies over the entire time period took place in an area >1,000 ha. Over the past 25 years, there was an increase to about 28% of the studies using areas >1,000 ha. Perhaps the increase in proportion of studies on larger tracts of land is due to the increase in the study of species requiring larger tracts of land, such as bears, mountain lions and wolverines.

Although in some cases it was difficult to categorize a given study, we did find that in general, the types of questions

Table 2—Proportion of studies of all animal groups listed in table 1 that were conducted in a wilderness environment. Results are reported at five-year intervals between 1937 and 1996.

Category	1937	1941	1946	1951	1956	1961	1966	1971	1976	1981	1986	1991	1996
Wilderness settings	0	3	4	4	5	6	8	10	8	8	10	10	11

biologists typically asked in wildlife studies was rather limited. Three general types of questions appear to prevail in the literature as determined from our analysis. About 26% of the studies involved examinations of animal food habits and food availability, 24% of the studies involved some form of habitat relationship or habitat use, and 23% of the studies involved the population dynamics of a given species.

Does Wilderness Have a Role in Wildlife Research?

Although the use of wilderness areas for wildlife research has been increasing in recent years, our analyses suggest that the overall use of wilderness areas for research is and has been limited. If this is true, the question is why? We raise this question in the light of the fact that wilderness areas have been touted as research centers, and because of the statement made in the paper on wildlife research in wilderness areas presented at the previous wilderness research conference (Starkey and Larson 1985), which stated that "Wilderness and National Park areas have historically provided excellent study areas for wildlife research."

The reasons appear to be that most wildlife studies have been conducted on species that are relatively common in a variety of non-wilderness landscapes, have an economic importance either as game or for fur or pose economic impacts because of damage to agricultural crops, depredation or disease. Many of these species are generally not found in abundance in most wilderness areas, but thrive in prairie, wetland, riparian and lowland forest habitats, which have not been included in wilderness because of their economic value for agriculture, livestock production and timber. Small game, upland birds and furbearers are also not high priorities for research in national parks, where hunting and trapping is prohibited (Garrett and Wright 1999).

The more recent increase in studies of breeding birds, such as the red-cockaded woodpecker in forested environments, seems to reflect, among other things, increased concerns over the adverse impacts of forest timber management practices (Conner and Rudolph 1991). The more recent increases in studies of habitat use by bears, carnivores and some breeding birds may reflect research projects spawned by the Endangered Species Act (Johnson 1979). It seems likely that this trend will continue.

Wilderness settings provide habitats that receive a minimal amount of human disturbance while providing the opportunity for natural disturbance and ecological processes to operate with minimal human interference (Starkey and Larson 1985). However, the price of maintaining undisturbed environments includes restrictions on use and access. We speculated that in planning a field research project, most researchers select study sites that are generally convenient to use, are easily accessible by motorized vehicle and amenable to the use of a variety of equipment/methods. This is often done to simplify logistics and limit expenses. The restrictions associated with wilderness typically complicate logistics and increase the expenses of doing research. It appears that many scientists have found it either not necessary, are not willing or simply cannot afford to work in wilderness settings unless the species of interest requires it.

The large spatial extent of most wilderness areas is generally considered an important attribute to some types of research because, among other things, it can provide a buffer against surrounding fragmentation and habitat disruption. However, our analysis has shown that the use of large study areas in research projects is uncommon. Some investigators have speculated that many biologists simply may not be comfortable working at large ecological scales (May 1994). In fact, the focus of most ecological studies has long been on relatively small spatial units, with the $1m^2$ plot being the dominant unit of analysis, and most ecological theory has developed from studies conducted on small spatial units (Kareiva and Anderson 1989). The story that seems to emerge is that the use of large undisturbed environments for study sites may have little attraction for most wildlife biologists. This factor clearly ties into the restrictions on access discussed above. However, over the past 25 years, there has been an apparent increase in the spatial scale of some analyses and a higher proportion of studies conducted in larger areas (i.e. >1,000 ha). This trend appears to be reflective of the overall increase in studies of wilderness-dependent species shown in table 2.

Wildlife biologists generally acknowledge that understanding the ecological complexities of natural environments typically requires long-term studies (Halvorson and Davis 1996). However, these are uncommonly rare in North America, particularly for the study of wildlife, even though there seems to be a universal appreciation of long-term studies. Pelton and van Manen (1996), in a survey of wildlife studies published in the *Journal of Wildlife Management,* found that 80% of the wildlife studies were based on <5 years data, and 65% were conducted over three years or less, which is generally the time period of a graduate student research project. The typical funding cycles for most research studies, combined with the need for quick results, create a strong disincentive for long-term study (Weatherhead 1986) and again may mitigate against using environments where logistic and ecological complexities may, of necessity, extend the duration of the study.

Wilderness Dependent Species

We believe it is unlikely that many of the factors described above will change in the near future. Consequently, we do not believe that wilderness areas are likely to be a setting for the study of the majority of wildlife species. Rather, the focus of research in wilderness areas will likely continue to be species that may be considered wilderness-dependent (Schoenfeld and Hendee 1978) - not because they require wilderness habitats per se, but because they require wilderness to avoid conflicts with humans and to decrease their vulnerability to human-caused mortality (Mattson 1997). Thus, while grizzly bears may tolerate the habitat disturbance associated with some forms of logging, they generally cannot tolerate the increases in human densities and activities associated with logging. In other words, for a species like grizzly bear, wilderness primarily represents an environment with few humans, where, as a consequence, it can find refuge.

In defining wilderness-dependent species in this manner, we exclude the many species that, for one reason or another, may at times conflict with humans and their use of the land.

Beaver in suburban drainages, geese on golf courses, coyotes on sheep ranches and birds in orchards are but a few examples of human/wildlife conflicts. There are likewise many species that may at times be vulnerable to human-caused mortality but whose population is little affected. Currently over 50,000 white-tailed deer are killed each year on Pennsylvania highways, yet the population has been unaffected. Instead, we focus on a far smaller number of species that can, if habitat conditions permit, come into constant conflict with humans *and* are usually vulnerable at all times to human mortality. For these species, wilderness offers both refuge and often the only possible place to study them.

Species falling into this category generally share three distinct biological characteristics (Mattson 1997):

1. They tend to be large, with relatively low rates of fecundity and therefore low potential population growth rate, thus making them more vulnerable to extirpation than populations of small animals with high reproductive potential.
2. They are more likely to be killed by humans because they pose a threat to humans or their property.
3. They may display behavioral traits such as aggressiveness that can make them a threat to human safety, thus predisposing them to lethal responses.

The anthropocentric threats faced by such species are ironic, considering the fact that surveys have shown that there is strong public support for the protection of these wilderness wildlife species (Kellert 1984). However, it seems indisputable that protection from human-caused mortality is primary to the survival of wilderness-dependent wildlife. Yet despite rigorous protection by federal endangered species laws, virtually all grizzly bears and wolves that die in the U. S. are killed by humans (Mattson and others 1996). Most of these deaths occur outside of national park wilderness areas, and many occur because humans are armed, often in the pursuit of game species, and perceive themselves to be threatened. Therefore, wilderness designation alone cannot guarantee the preservation of such species.

To summarize, we have provided an overview of wildlife research in North America, pointing out that although wilderness areas seem to be nonessential for a majority of studies on the majority of species, they are essential for furthering our understanding of wilderness-dependent species. In making this statement, we do not mean to imply that wilderness areas are not important baselines against which to monitor factors impacting wildlife in non-wilderness situations (Peek 1980). Because of this and other factors, we also do not want to imply that the present situation—of a relatively low proportion of wildlife studies conducted in wilderness areas—is necessarily desirable.

In the following sections, we present an overview of contemporary research on selected wilderness-dependent wildlife species, focusing on the questions that are being asked and seeking to determine whether wildlife research in wilderness areas can help us better answer them. In this overview we focus on wolverines (*Gulo gulo*), mountain lions (*Felis concolor*), grizzly bears (*Ursus arctos horribilis)*, wolves (*Canis lupus*) and lynx (*Lynx rufus*).

Wilderness Research and Wolverines

The wolverine is characterized as one of North America's rarest mammals and least understood carnivores (Banci 1994). Wolverines lead a solitary lifestyle, occupying large home ranges at low population densities in areas remote from humans and human developments (Banci 1994). All three factors have combined to make research studies difficult and therefore infrequent.

North American field studies completed in the 1980s included two in Alaska (Gardner 1985; Magoun 1985), one in the Yukon (Banci 1987) and one in Montana (Hornocker and Hash 1981). An additional study completed in 1996 in central Idaho (Copeland 1996) added to our knowledge of wolverine presence, ecology, spatial characteristics, movement, demographics, social structure and habitat use.

The most common attributes derived from field studies of wolverine are large spatial requirements, low population density, and nonspecific habitat requirements in terms of vegetative structure (Copeland 1996). Hornocker and Hash (1981) described a wolverine population in northwest Montana as demographically stable, but socially dynamic due to periodic turnover caused by trapping mortality. Their research was the only field study of wolverines in the contiguous U.S. before Copeland (1996). Gardner (1985) studied wolverines in south-central Alaska and concluded that the Alaskan population was more spatially stable than the Montana population. Magoun (1985) included behavior in her assessment of factors important to management of an arctic Alaska wolverine population dependent on migrating ungulates. Banci (1987) analyzed wolverine carcasses to determine reproductive morphology and food habits and studied wolverine ecology and habitat use in the Yukon.

A main theme that has emerged from past research on wolverines is that information necessary for the management and conservation of wolverine populations in Western forests is not available (Banci 1994). Of paramount need is basic information on the occurrence and distribution of wolverines in the conterminous United States, and on whether these populations are self-sufficient (Banci 1994).

Results from research conducted in central Idaho include recording the largest spatial requirements for wolverine, with male home ranges averaging 1,522 km^2 and female home ranges averaging 384 km^2 (Copeland 1996). In addition to documentation of spatial requirements, Copeland (1996) described evidence of a resident adult wolverine associating with a sub-adult wolverine, behavior not previously recorded. Research results reported from this study were an outcome of advances in biotelemetry, enabling researchers to study wolverine ecology in a more comprehensive manner.

Survey methods to detect the presence of wolverines have also benefited as a result of new technology. William Zielinski, research wildlife biologist with the Pacific Southwest Research Station, and Thomas E. Kucera, of the Department of Environmental Science, Policy, and Management, University of California-Berkeley, have produced a document detailing successful methods used to detect the presence of forest carnivores, including wolverines. The survey methods

described in the manual produce necessary, reliable and verifiable information on the distribution of wolverines (Zielinski and Kucera 1995). Detection methods described in the manual include remote camera, track plate and snow-tracking methods.

Wolverine field studies confirm a clear association between wolverine presence and refugia. Hatler (1989) commented that reduction of wilderness "refugia" through access and alienation for timber and mineral extraction may be the greatest threat to local population viability. Banci (1994) confirms that persistence of a population of wolverine in southwestern Alberta is due to the presence of large refugia, in the form of national parks.

The absence of wolverines from historical ranges may be related to human activity as much as reductions in habitat (Copeland 1996). Reduction in the wolverine's historical North American distribution and numbers is suspected to be a result of human encroachment (Banci 1994). Human presence within historical wolverine range may have regulated population growth and stability or simply displaced wolverines through habitat alteration and destruction (Copeland 1996). 'Female wolverines used secluded high-elevation cirque basins in Idaho for natal den sites. Protection of natal denning habitat from human disturbance is critical for the persistence of wolverine in Idaho (Copeland 1996). Human disturbance at maternal dens resulted in den abandonment, but not kit abandonment The advent of increased use of wilderness areas by snowmobilers and other winter recreationists in the 1990s is believed to have displaced wolverines from potential denning habitat.

Limited information, indicates that wolverines appear more susceptible to natural fluctuations in scavenging opportunities and may have lower lifetime productivity than even grizzly bears (Weaver and others 1996). The reproductive rate for females was less than 1 kit/female/year (Copeland 1996).

Increased public awareness of the habitat requirements of wolverines and the role they play in the functioning of wilderness ecosystems will be key in their conservation. Wolverines' current listing as "sensitive" or as a "management indicator species" on most national forests throughout their range should provide increased levels of administrative and legal protection (Zielinski and Gill 1997).

New research initiatives and the accompanying results will help provide forest managers with the information needed to determine the ecosystem components necessary to sustain wolverine populations. Planning for species conservation can be less difficult and more beneficial than trying to restore declining populations.

Wolverines thus constitute a classic wilderness-dependent species. They require large spatial areas with a full array of seasonal habitats to maintain their solitary lifestyle, as well as the necessary refugia from human influences. Ideally, such wilderness refugia should be connected to other refugia through landscape linkages (Weaver and others 1996). An evaluation of whether there is sufficient habitat to support self-sustaining populations and to provide for dispersal corridors in the Pacific Northwest coast and mountains, Sierra Nevada and northern Rocky Mountain forest ecoprovinces is a high research priority (Bianci 1994).

Wilderness Research and Mountain Lions

Mountain lions have adapted to - and been studied in - a wide range of habitats in North America. However, wilderness areas have provided unique research opportunities to study natural regulation, mountain lion social systems, home ranges and habitat use.

The study of natural regulation is important to wilderness wildlife researchers because results of research studies have broad implications for management of big game. Natural regulation, by definition, can take place only in ecosystems where predator, prey and habitat are not impacted by human activity. Predator-prey relationships constitute one form of natural regulation that can be defined as the set of controlling mechanisms that serves to limit population density in the absence of human influence (Peek 1980). Ideally, this research is conducted in a wilderness setting that includes the opportunity to encompass all phases of population fluctuation of mountain lions and their ungulate prey.

Hornocker (1970) began an investigation to gather information on mountain lion population dynamics and to assess the lion's role as a predator in the Idaho Primitive Area (now the Frank Church River of No Return Wilderness). Hornocker primarily used mark-release-recapture techniques, with tracking dogs and snow tracking, to locate the mountain lions. He discovered that in spite of both lion and human predation, populations of mule deer (*Odocoileus hemionus*) and elk (*Cervus canadensis*), increased during a four-year period during which the lion population remained stable. Hornocker (1970) postulated that, "Intraspecific relationships, manifested through territoriality, acted to limit numbers of lions and maintain population stability. Dispersal and mortality of young individuals appeared to be an important limiting mechanism."

Radio-tracking, developed successfully by Craighead and Craighead (1972) and used for tracking grizzly bears, was implemented in subsequent mountain lion research in the Idaho Primitive Area by Seidensticker and others (1972). The use of biotelemetry enabled the researchers to observe the highly secretive mountain lion and describe its social system. Seidensticker and others (1972:77) concluded, "that the lion land tenure maintains the density of breeding adults below a level set by food supply in terms of absolute numbers of mule deer and elk. Variation in mountain lion environmental structure resulted in variations in the suitability of areas and affected the amount of terrain a resident lion utilized. The amount of terrain used by a resident mountain lion as well as the degree of home area overlap between resident females, i.e., density of breeding population, was set by a vegetation-topography/prey numbers-vulnerability complex."

These early mountain lion research studies identified the social system and intrinsic regulatory mechanisms involving territoriality and land tenure, which provides baseline information needed to manage and conserve this species and other solitary cats (Hornocker and Bailey 1986). They were possible because of the extent of the large wilderness areas in central Idaho. It was through this work that the mountain

lion was designated a game animal in Idaho (Hornocker 1971). Subsequently, this species was designated a game animal in most states and provinces that maintain populations, and an orderly regulated harvest was then established (Peek 1999).

Sweanor (1990) expanded the research completed by Seidensticker and others (1972) by completing a comprehensive study of mountain lion social behavior in a desert environment. In this study, Sweanor (1990) concluded that mountain lion populations in the San Andres Mountains of New Mexico appear to be self-regulating. Self-regulation probably is imposed via three mechanisms: social intolerance, mortality from intraspecific killing and dispersal.

Research studies have employed intensive search, capture, marking, recapture and radiotelemetry techniques and defined analytical methods. The research studies areas include Alberta (Ross and Jalkotzy 1992), British Colombia (Spreadbury 1989), Idaho (Seidensticker and others 1972), New Mexico (Logan and others 1996), Utah (Lindzey and others 1994) and Wyoming (Logan and others 1986). These studies produced the most reliable estimates of mountain lion density. Maximum densities reached 0.6 to 2.2 resident adults or 1.4 to 4.7 mountain lions per 100 square kilometers (Logan and Sweanor 1999).

Important findings from the past 25 years of mountain lion research include these results (Logan and Sweanor 1999):

1. Deer are mountain lions most important food, although other species of ungulates are eaten depending on local abundance and vulnerability (Anderson 1983).
2. Mountain lions can be cannibalistic. Males have killed and cannibalized cubs (Hemker and others 1982; Logan and others 1996; Spreadbury and others 1996; Young 1946), adult females (Beier and Barrett 1993) and other adult males (Williams 1992).
3. How often that mountain lions kill prey and their rates of consumption largely depend on the energy requirements of the individual population units and the biomass of the prey (Logan and Sweanor 1999).
4. Mountain lions are polygamous and promiscuous (Anderson 1983; Seidensticker and others 1973; Sweanor 1990).
5. The social organization of mountain lions has been described as a land tenure system where dominance over an area is held initially by the resident adult mountain lions occupying the area (Seidensticker and others 1973).
6. Home ranges of mountain lions have been studied extensively using radiotelemetry; in general, home ranges of males are larger than females within the same population by factors of 1.5 to 5.

Gaps in information concerning mountain lion ecology include little information on the age structure of mountain lion populations, data on sex and age-specific survival rates, the effects of parasites and disease in mountain lions and quantitative information on rates of mountain lion population increase (Logan and Sweanor 1999).

Wilderness areas are important to mountain lion research and conservation for several reasons including: (1) the potential to provide a diversity of genotypes when selection outside of wilderness areas is heavily influenced by humans, (2) the potential to conduct long-term research, spanning more than 10 years, to determine to what extent mountain lion predation limits or regulates prey populations (Logan and Sweanor 1999) and (3) knowledge of how mountain lions use habitat in an unaltered landscape which should help managers identify potential degradation and fragmentation, locations of migration and dispersal corridors.

Protected mountain lion populations, particularly in national park wilderness areas function as robust biological savings accounts which contribute to population resilience (Weaver and others 1996) by countering management-related mistakes in exploited subpopulations and increased mortality in adjacent fragmented habitat (Logan and others 1996; Murphy 1998). Protected areas enable subpopulations to evolve relatively naturally, providing a diversity of genotypes when selection is heavily influenced by humans (Logan and others 1996).

Long-term (greater than 10 years) experimental research will be needed to determine to what extent mountain lion predation limits or regulates prey populations. Murphy (1998) states, "I am unaware of a single study of cougar population dynamics that has spanned even one full cycle of major fluctuation in its principal prey." Studies have not been long enough to include all the phases of fluctuation of a population of the mountain lion and its ungulate prey.

Knowing how mountain lions use habitat in wilderness areas should help land managers identify potential degradation and fragmentation and locations of dispersal and migration corridors. Habitat loss and fragmentation are the greatest threats to long-term mountain lion conservation (Logan and others 1996).

Wilderness Research and Grizzly Bears

The nature of the grizzly bear as an animal that requires significant amounts of space, solitude from excessive human disturbance and a broad range of diverse and available habitats makes it a prime example of a wilderness animal (Servheen 1985). Space and solitude are essential for maintaining bears in perpetuity, therefore research and management efforts should focus on the largest areas of prime bear habitat (Craighead and others 1982).

Evidence of a decline of grizzlies in Yellowstone, combined with aroused public concern over the fate of this powerful carnivore in the contiguous 48 states, prompted the director of the U.S. Fish and Wildlife Service, following scientific and public review, to declare the grizzly bear a threatened species subject to the rules and regulations of the Endangered Species Act of 1973 (Craighead and others 1982). This designation emphasized the importance of critically defining and analyzing components of grizzly bear habitat and relating this information to the numbers and distribution of the bears (Craighead and others 1982).

The grizzly has survived through the past decade primarily because suitable habitat was preserved by the Wilderness Act of 1964, which established a National Wilderness Preservation System. The focus of research on grizzly bears, from the 1970s to the 1990s, has been on describing, analyzing and mapping critical wilderness habitat occupied by bears.

Critical habitat was delimited and land areas classified that are: (1) in wilderness status and currently supporting viable grizzly bear populations; (2) occupied by grizzly bears, but subject to high priority land use conflicts; and (3) wilderness or *de facto* wilderness no longer supporting viable grizzly bear populations, but having the habitat potential to do so (Craighead and others 1982). Craighead and others (1982) suggested that researchers use these broad habitat classifications as a starting point for intensive study and scientifically describing the areas delineated.

Many habitat studies have been completed on various aspects of grizzly bear habitat south of Canada, including habitat surveys, establishment of criteria for evaluating habitat, development of habitat rating systems, development of habitat-typing and mapping techniques, analyses of food plant distribution and occurrence and food habits of grizzly bears in relation to habitat types and generalized vegetation complexes. Craighead and others (1982) utilized satellite multispectral imagery and ecological ground truth data to construct thematic, computerized vegetation type maps. Studies of the food habits and habitat requirements of grizzly bears, in wilderness areas, has revealed that environmental characteristics essential to the maintenance of a grizzly bear population include (Craighead and others 1982):

1) Space – large wilderness areas of national parks and national forests are essential. Home ranges encompass an area up to 2,600 to 4,000 sq. km.

2) Isolation – Habitat must be isolated from developed areas and conflicts with man.

3) Sanitation – Disposal of garbage at communities adjacent to essential habitat to eliminate bear-man conflicts.

4) Food – Abundance of natural foods must be available from April to November.

5) Denning – Wilderness areas that provide the specific denning requirements (2,100-2,750 m altitude in areas of heavy snowfall) and isolation during the denning period.

6) Vegetation Types – Wide range of vegetation types.

7) Safety – Protection from human depredation and competitive use of habitat.

A perceived threat to wilderness areas, which has influenced current trends in grizzly bear research, is a result of the scientific use of wilderness (Franklin 1987, Parsons and Graber 1990). Research in wilderness areas often requires the use of permanent markers, mechanized equipment and/or destructive sampling. The trend in the past 20 years or so, since the advent of radiotelemetry, has been to capture and radio-collar grizzly bears in wilderness areas to obtain population parameters. There is evidence that an intensive trapping program that subjects an already stressed population to a high degree of disruption and human-conditioning is highly questionable and not biologically or financially justifiable (Craighead and others 1982).

In 1985, the development of a population monitoring system was identified as a high priority item in the Grizzly Bear Recovery Plan for the northern Continental Divide ecosystem. There is need to assess population change over time without jeopardizing the population by subjecting bears to capture and placement of radio collars. Identified design criteria that must be met by any trend monitoring system include: 1) it should be cost-effective; 2) it must measure a representative sample of an acceptable size; 3) it must not cause more than minimal disturbance to the bears and the ecosystem; and 4) it must be easy to use (Eno and others 1986).

In the northern Continental Divide ecosystem, several methods to assess population trends were tested from 1982 to 1984. These included helicopter surveys of known denning areas when bears emerged in the spring, helicopter surveys of shrub fields in autumn when the shrub fruit crop was at its peak, and aerial and ground surveys of open alpine areas in summer (Eno and others 1986).

New advances in genetic technology allow identification of species, sex and individuals from DNA extracted from bear hair and scats without handling bears (Waits, unpublished). These new techniques are less expensive and less disruptive to bears than traditional censuses using radiotelemetry and radio-tracking. Hair samples are collected at bait stations, and bear sign is collected along trails frequented by bears. This information should enable researchers to document ecosystem-wide population trends. Research is now being conducted at Glacier National Park using genetic technology.

Wolves and Wilderness Research

Wolf research in a wilderness setting began as early as 1958 in Isle Royale National Park (Mech 1966). Researchers were interested primarily in understanding the factors that regulated wolf and moose (*Alces alces*) populations on the island. Isle Royale National Park provided the perfect opportunity for this type of study as the wildlife populations were confined to this isolated island, with no real possibilities for emigration or immigration. In terms of faunal diversity, the island is also a relatively simple system. A number of bird and mammal species that exist on the mainland have never reached the island or have since disappeared from it. The community of life on the island is therefore easier to work with and understand than similar habitats in Minnesota and Ontario (Allen 1993).

Another important advantage is that no hunting or trapping is allowed on the island. If Isle Royale had been hunted, the age structure of the moose herd would have been altered, and many moose would have been shot long before they were old enough to be killed by the wolf (Allen 1993). If beaver had been subject to trapping, the summer food supply of wolves would have been reduced. If wolves had been exposed to control or illegal shooting, the social relationship of individuals and packs would have been disrupted. Finally, the Park is closed to visitor-use during the winter, and visitor activities during the summer are relatively nonintrusive and closely monitored (Wright 1996).

The research program at Isle Royale National Park has concentrated on three main topics over the years: wolf predation patterns, wolf behavior and ecology and moose population dynamics. Studies of wolf predation patterns emphasized the age and sex of moose killed, the other prey species, hunting success and the effect of snow depth on predation success and activities. Research on wolf behavior and ecology focused on social hierarchy in the packs, courtship and breeding, territoriality, communication, denning and rendezvous sites, reproduction, relationships with non-prey species and movements. Field observations of moose population dynamics included population size, age and sex

ratios and productivity, habitat relationships, food habits and mortality factors (Wright 1996).

Important insights into predator-prey relationships have been gained in the almost 40 years of wilderness research at Isle Royale National Park, but not without controversy. Evidence of stable limit cycles at Isle Royale was presented by Peterson and others (1984) and reconfirmed by Messier (1991). Stable limit cycles imply density-independent predation during increases in moose density, inversely density-dependent predation during moose declines, regular periods of oscillation, no predator pits and nonregulating predation throughout the cycle (Van Ballenberghe and Ballard 1994).

Keith (1983) proposed recurrent fluctuations as a general model for moose-wolf interactions when bears were absent, and Van Ballenberghe (1987) interpreted the Isle Royale data as evidence of this, in contrast to stable-limit cycles. Recurrent fluctuations occur if predation is mainly density-independent or inversely density-dependent and not regulating. Van Ballenberghe and Ballard (1994) reviewed the recent literature on moose-predator interactions to determine whether moose numbers are limited or regulated by predation, and if so, under what conditions. The authors conclude that "the conditions required for recurrent fluctuations include minimal influence by humans on simple moose-wolf ecosystems containing few alternative prey. The Isle Royale data from 1959 to 1969 represent periods of increase (1959-1969), decrease (1970-1980) and increase (1981-1986) (Messier 1991) that fit the recurrent fluctuation model." They further state that, "Because Isle Royale is a unique example of a moose-predator system lacking bears, it may be the best area to test the recurrent fluctuation model for naturally regulated ecosystems."

The central tenet of natural regulation envisioned by Cole (1971) and D. B. Houston, (unpublished manuscript)—that moose exhibit intrinsic demographic responses sufficient to stabilize population growth—was not supported by a chronological review of moose fluctuations at Isle Royale completed by Peterson (1999). Depressed wolf numbers led to an increase in moose which continued until moose overshot their food supply and crashed from starvation.

Houston (1982) stressed that the lack of wolf predation for the majority of this century in most national parks was a significant ecological deficiency (Peterson 1999). Wilderness research opportunities for studying wolves in recent years have involved monitoring efforts and documenting the restoration of large carnivores in wilderness areas. The restoration of wolves to Yellowstone National Park and the Middle Fork of the Salmon River, Idaho in 1995 have enhanced the value of these areas as ecological research sites (Phillips and Smith 1996) and provided wilderness researchers with a unique opportunity. Peek (1999) states that, "As wolves continue to adjust to this area, opportunities to investigate their interactions with other predators, most especially the mountain lion which shares a common prey base, and to examine the effects on prey that are game species are obviously great." An investigation into the relationships of four carnivores—mountain lions, wolves, coyotes and bobcats—was initiated in December 1998 in the Big Creek drainage in central Idaho.

The major need in future research is to understand the role of wolf predation in regulating ungulate prey (Eno and others 1986). Wolves and their prey are long-lived (Peterson and others 1984), and unraveling predator-prey dynamics requires a long-term research commitment. Long-term studies often show that systems, even those considered to be relatively simple, are in fact very complex. Over the course of the Isle Royale research, different perspectives of what is going on emerged at different points in the time period. It seems clear that if the research had been terminated at any one of these points, our biological understanding of the system would be far different and probably flawed (Wright 1999).

Lynx and Wilderness Research

The lynx occurs primarily in the boreal forests of Alaska and Canada, but its range extends south into the northern portion of the Western mountains, where environmental conditions at high elevations support boreal forest habitats similar to those found in northern regions. The distribution of the lynx appears to be tied to that of the snowshoe hare (*Lepus americana*), and both species are confined to northern forest environments (Hall 1981). Snowshoe hares comprise 35%-97% of the lynx diet (Koehler and Aubry 1994). Hares not only determine where lynx are found, but also influence how many lynx may occupy an area.

The conservation of lynx is of greatest concern in the Western mountains of the conterminous United States at the southern periphery of the species' range (Koehler and Aubry 1994). The largest populations in the United States, outside of Alaska, occur in the northern portions of Washington and Montana. A current description of lynx distribution in Washington indicates that lynx are now restricted to the northeastern Cascade Range and several isolated areas in the Okanogan Highlands of northeastern Washington (Koehler and Aubry 1994). The Okanogan population was studied with radiotelemetry in the 1980s (Brittell and others 1989; Koehler 1990), and most of the information available on the ecology, population dynamics and management of the lynx in the Western mountains of the United States comes from these studies. Historical records indicate that lynx were relatively numerous in the panhandle of Idaho and western Montana.

Recent lynx records are scarce from the Western mountains and reliable information on the current distribution and abundance of lynx populations throughout the western United States is needed (Koehler and Aubry 1994). Only five lynx studies have ever been conducted in the Western mountains of the United States, including two in Washington and three in Montana. These studies have focused on home range and habitat use; information on demography, food habits, dispersal and denning sites is lacking. Koehler and Aubry (1994) state that studies on foraging ecology, den site characteristics and habitat relationships at the landscape scale are urgently needed.

Conclusions

Wilderness is vital to the conservation of wildlife species prone to conflict with humans as well as to species that require wilderness to provide an array of seasonal habitats necessary for survival. Research in wilderness areas is not necessary or practical for the majority of wildlife species

because these animals do not fit the requirements for wilderness-dependent wildlife.

Wilderness wildlife researchers must remind themselves that it is not so much the nature of wilderness that demands the efforts of researchers, but the animals that exist only in wilderness areas. Mountain lion research can be accomplished outside of wilderness areas because mountain lions exist in a variety of habitats. Grizzly bear, wolf, lynx and wolverine research can only occur in wilderness areas because these are the only habitats where these animals can be found in sufficient numbers.

One facet of research that depends on wilderness areas, especially those in national parks, is the study of natural regulation. The study of natural regulation can only take place in wilderness settings where predator, prey and habitat are not impacted by uncontrolled human activity and human harvest. This may rule out wilderness settings subject to a high level of hunter harvest.

The presence of large areas with a high degree of integrity and continuity means that a wilderness harbors substantial information of benefit to science and society (Graber 1985; Noss 1991). However, wilderness wildlife research has been primarily limited to species that are wilderness-dependent and the study of natural regulation. Many more wildlife research questions can be answered outside of wilderness areas more easily and at less cost. Perhaps the focus on wilderness research should be on ecological processes rather than specific wildlife species, unless we are trying to unravel specific survival questions pertaining to wilderness-dependent wildlife or studying natural regulation.

We conclude by stating that wilderness is important to the conservation of wilderness-dependent species, but conclusions drawn from analyses of the published literature indicate that wilderness and wildlife research is limited in scope on the majority of wildlife species. This trend will no doubt continue due to limited funding and accessibility. There may be no scientific basis for studying a population of mule deer in a wilderness area, as opposed to a population in a habitat adjacent to a populated area, unless the basis for the research is to assess the impacts of human-caused mortality or the study of natural regulation.

Although wilderness wildlife research, for all practical purposes, is limited to the study of wilderness-dependent wildlife and natural regulation, researchers should be aware of and make greater use of the opportunities to monitor wildlife populations in wilderness settings. Monitoring wildlife in wilderness ecosystems may be used to warn of impending environmental change across broad geographic areas. Davis and Halvorson (1988) considered the national park ecosystems to be "miner's canaries" and the concept applies to many areas that are relatively undisturbed by human presence (Peek 1999).

References

Allen, A. A. 1932. Game research progress in 1932. Transactions 19th American Game Conference. 19:216-220.

Allen, D.L. 1993. Wolves of Minong Isle Royale's Wild Community. University of Michigan Press, Ann Arbor, MI. 499p.

Anderson, A.E. 1983. A critical review of literature on puma (*Felis concolor*). Colorado Division of Wildlife Special Report 54. 91p.

Banci, V. A. 1994 Wolverine Pages 99-127 *in* Ruggiero, Leonard F.; Aubry, Keith B.; Buskirk, Steven W.; Lyon, L. Jack; Zielinski, William J. 1994. The Scientific Basis for Conserving Forest Carnivores: American Marten, Fisher, Lynx, and Wolverine. U.S. Department of Agriculture, Forest Service, General Technical Report RM-254. 184p.

Banci, V. 1987. Ecology and behavior of wolverine in Yukon. Burnaby, B.C.: Simon Fraser University. M.S. Thesis. 178p.

Beier, P.; Barrett, R.H. 1993. The cougar in the Santa Ana mountain range, California. Final Report. Orange County Cooperative Mountain Lion Study. 104p.

Borland, H.G. 1975. The history of wildlife in America. National Wildlife Federation, Washington, D.C.

Brittell, J.D.; Poelker, R.J.; Sweeney, S.J. 1989. Native cats of Washington. Olympic, WA: Washington Dept. of Wildlife. 169p.

Cole, G.F. 1971. An ecological rationale for the natural or artificial regulation of native ungulates in parks. North American Wildlife and Natural Resources Conference 36:417-425.

Conner, R.N.; Rudolph, D.C. 1991. Effects of mid-story reduction and thinning in Red-cockaded woodpecker cavity tree clusters. Wildlife Society Bulletin 19:63-66.

Copeland, Jeffrey P. 1996. Biology of the Wolverine in Central Idaho. Moscow, ID: University of Idaho. M.S. Thesis 138p.

Craighead, F.C., Jr. ; Craighead, J.J. 1972. Grizzly bear prehibernation and denning activities as determined by radiotracking. Wildlife Monograph 32. 35p.

Craighead, J.J.; Sumner, J.S.; Scaggs, G.B. 1982. A Definitive System for Analysis of Grizzly Bear Habitat and other Wilderness Resources. Wildlife-Wildlands Institute Monograph 1, University of Montana, Missoula, MT. 279p.

Davis, G.E.; Halvorson, W.L. 1988. Inventory and monitoring of natural resources in Channel Islands National Park, California. USDI National Park Service, Channel Islands National Park, Ventura, CA. 31p.

Eno, A.S.; Di Silvestro, R.L. Chandler, W.J. 1986. Audubon Wildlife Report. The National Audubon Society, New York, N.Y. pp. 962.

Fagan, B.M. 1989. People of the earth: An introduction to world prehistory. Scott, Foresman Inc., Glenview, IL.

Franklin, J.F. 1987. Scientific use of wilderness. Pages 42-46 *in* Lucas, R.C. compiler. Proceedings-national wilderness research conference: issues, state-of-knowledge, future directions. U.S. Forest Service General Technical Report INT-220.

Gardner, C. L. 1985. The ecology of wolverines in southcentral Alaska. Fairbanks, AK: University of Alaska. M.S. Thesis. 82p.

Garrett, L.K.; Wright, R.G. 1999. Prioritizing the Research and Monitoring Needs of Terrestrial Mammals in National Parks. In Press George Wright Forum.

Graber, D.M. 1985. Managing for Uncertainty: National Parks as Ecological Reserves.

George Wright Forum. Hancock, MI.

Gray, G. G. 1993. Wildlife and people. University of Illinios Press, Urbana.

Greeley, W. B. 1931. The American Game Association Transactions 18th American Game Conference. 18:95-100.

Hall, E.R. 1981. The mammals of North America. 2nd ed. New York: John Wiley and Sons. 1181p.

Halvorson, W.L.; Davis, G.E. eds. Ecosystem Management in the National Parks. University of Arizona, Tuscon, AZ.

Hatler, D.F. 1989. A wolverine management strategy for British Colombia. Wildlife Bulletin. ISSN 0829-9560; no. B-60, Wildlife Branch, Ministry of Environment, Victoria, B.C. 124p.

Hemker, T.P.; Lindzey, F.G.; Ackerman, B.B.; Button, A.J. 1982. Survival of cougar cubs in a non-hunted population. Pages 327-332 *in* Miller, S.D.; Everett, D.D. eds. Cats of the World: biology, conservation and management. National Wildlife Federation, Washington, D.C.

Houston, D.B. 1982. The northern Yellowstone elk herd: ecology and management. Macmillan, New York, New York.

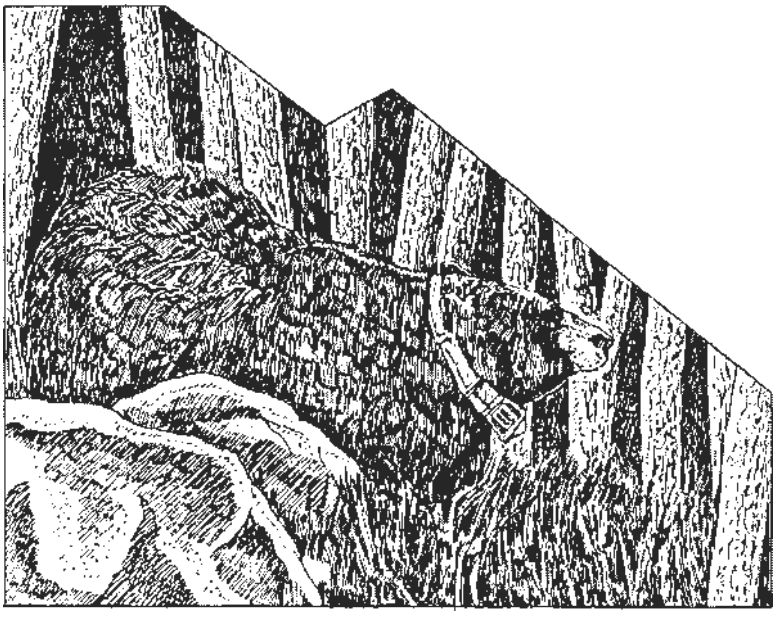
Hornocker, M.G. 1970 An analysis of mountain lion predation upon mule deer and elk in the Idaho Primitive Area. Wildlife Monograph 21. 39p.

Hornocker, M.G. 1971. Suggestions for the management of mountain lions as trophy species in the Intermountain Region. Proc. Western Association of State Game and Fish Commissioners 51:399-402.

Hornocker, M.; Bailey, T. 1986. Natural regulation in three species of felids. *In* Miller, S.D.; Everett, D.D. editors. Cats of the World:

biology, conservation, and management. National Wildlife Federation, Washington, D.C. pp 211-220.
Hornocker, M.G.; Hash, H.S. 1981. Ecology of the wolverine in northwestern Montana. Canadian Journal of Zoology. 59: 1286-1301.
Johnson, M.K. 1979. Review of endangered species: policies and legislation. Wildlife Society Bulletin 7:79-93.
Keith, L.B. 1983. Population dynamics of wolves. Canadian Wildlife Service. No. 45: 66-77.
Koehler, G.M. 1990. Population and habitat characteristics of lynx and snowshoe hares in north central Washington. Canadian Journal of Zoology. 68:845-851.
Koehler, G.M.; Aubry, K. A. Lynx *in* Pages 74-98 *in* Ruggiero, Leonard F.; Aubry, Keith B.; Buskirk, Steven W.; Lyon, L. Jack; Zielinski, William J. 1994. The Scientific Basis for Conserving Forest Carnivores: American Marten, Fisher, Lynx, and Wolverine. U.S. Department of Agriculture, Forest Service, General Technical Report RM-254. 184p.
Kareiva, P.; Anderson, M. 1989. Spatial aspects of species interactions: the wedding of models and experiments. Pages 35-50 *in* Hastings, A. Ed. Community Ecology. Springer-Verlag, New York.
Kellert, S.R. 1984. Public perceptions of predators, particularly the wolf and coyote. Biological Conservation 31: 167-189.
Leopold, A. 1930. Report to the American game conference on an American game policy. Transactions 17th American Game Conference 17:284-309.
Lindzey, F.G.; Van Sickle, W.D.; Ackerman, B.B.; Barnhurst, D.; Hemker, T.P.; Laing, S.P. 1994. Cougar population dynamics in southern Utah. Journal of Wildlife Management 58:619-624.
Logan, K.A.; Irwin, L.L.; Skinner, R. 1986. Characteristics of a hunted mountain lion population in Wyoming. Wildlife Society Bulletin 13:257-262.
Logan, K. A.; Sweanor, L. L.; Hornocker, M.G. 1996. Cougars of the San Andres Mountains, New Mexico. Final Report, Federal Aid in Wildlife Restoration Project W-128R. New Mexico Department of Game and Fish., Santa Fe. 280p.
Logan, K. A.; Sweanor, L L. 1999 *in press in* Demarais, S.; Krausman, P. editors. Ecology and Management of Large Mammals in North America. Prentice Hall, N.J.
Magoun, A.J. 1985. Population characteristics, ecology and management of wolverines in northwestern Alaska. Fairbanks, AK: University of Alaska. Ph.D. Dissertation. 197p.
Mattson, D.J.; Herrero, S.; Wright, R.G.; Pease, C.M. 1996. Science and management of Rocky Mountain grizzly bears. Conservation Biology 10:1013-1025.
Mattson, D.J. 1997. Wilderness-dependent wildlife. International Journal of Wilderness (3):34-38.
May, R.M. 1994. The effects of spatial scale on ecological questions and answers. Pages 1-39 *in* Edwards, P.J.; May, R.M.; Webb, N.R. Eds. Large-Scale Ecology and Conservation Biology. Blackwell Science Ltd. Oxford, UK.
McCullough, D.R. 1996. Spatially structured populations and harvest theory. Journal of Wildlife Management 60:1-9.
Mech, D.L. 1966. The wolves of Isle Royale. USDI National Park Service, Fauna Ser. 7, 210p.
Messier, F. 1991. The significance of limiting and regulating factors on the demography of moose and white-tailed deer. Journal of Animal Ecology 63:377-393.
Murphy, K.M. 1998. The ecology of the puma (*Puma concolor*) in the northern Yellowstone ecosystem: interactions with prey, bears, and humans. Ph.D. Dissertation. University of Idaho, Moscow, ID. 147p.
Noss, R.F. 1991. Sustainability in Wilderness. Conservation Biology 5:120-121.
Parsons, D.J.; Graber, D. 1990. Horses, helicopters and hi-tech: managing science in wilderness. Pages 90-94 *in* Reed, P.C. compiler. Preparing to manage wilderness in the 21st century. U.S. Forest Service General Technical Report SE-66.
Peek, James M. 1980. Natural Regulation of Ungulates (What Constitutes A Real Wilderness?). Wildlife Society Bulletin 8(3): 217-227.
Peek, J. M. 1986. A review of wildlife management. Englewood Cliffs, N.J.: Prentice Hall. 486p.
Peek, James M. 1999. A Proposal to Establish a Monitoring Program for The University of Idaho Taylor Ranch Facility and The Adjacent Frank Church River-Of-No-Return Wilderness. University of Idaho, Moscow, ID 46p.
Pelton, M. R.; van Manen, F.T. Benefits and pitfalls of long-term research: A case study of black bears in Great Smoky Mountains National Park. Wildlife Society Bulletin 24:443-450
Peterson, R.O.; Page, R.E.; Dodge, K.M. 1984. Wolves, moose , and the allometry of population cycles. Science 224:1350-1352.
Peterson, R.O. 1999. Wolf-moose interaction on Isle Royale: the end of natural regulation? Ecological Applications 9: 10-16.
Phillips, M.K.; Smith, D. W. 1996. The wolves of Yellowstone. Voyageur Press, Stillwater, Minnesota.
Ross, P.I.; Jalkotzy, M.G. 1992. Characteristics of a hunted population of cougars in southwestern Alberta. Journal of Wildlife Management 56:417-426.
Schoenfeld, C. A. and J. Hendee. 1978. Wildlife management in wilderness. The Boxwood Press, Pacific Grove, CA.
Seidensticker, J.C. IV; Hornocker, M.G.; Wiles, W.V.; Messick, J.P. 1972. Mountain lion social organization in the Idaho Primitive Area. Wildlife Monograph 35. 60p.
Servheen, C. 1985. Biological Requirements of a Wilderness Species. A paper presented at the National Wilderness Research Conference, Fort Collins, CO, July 23-26, 1985.
Shepard, P. 1973. The tender carnivore and the sacred game. C. Scribners, Sons, New York.
Spreadbury, B. 1989. Cougar ecology and related management implications and strategies in southeastern British Colombia. Journal of Wildlife Management 60: 962-969.
Spreadbury, B.R.; Musil, K.; Musil, J.; Kaisner, C.; Kovak, J. 1996. Cougar population characteristics in southeastern British Colombia. Journal of Wildlife Management 60:962-969.
Starkey, E.E.; Larson, G.L. 1985. Fish and Wildlife Research and Wilderness in the United States: A State-of Knowledge Review. Pages 178-190 *in* Lucas, R.C. compiler. Proceedings-national wilderness research conference: issues, state-of-knowledge, future directions. U.S. Forest Service General Technical Report INT-220.
Sweanor, L.L. 1990. Mountain lion social organization in a desert environment. M.S. Thesis. University of Idaho, Moscow, ID. 172p.
Van Ballenberghe, V. 1987. Effects of predation on wolf numbers: a review of recent North American studies. Swed. Wildl. Res. Viltrevy Suppl. No. 1 pp. 431-460.
Van Ballenberghe, V.; Ballard, W.B. 1994. Limitation and regulation of moose populations: the role of predation. Canadian Journal of Zoology 72: 2071-2077.
Weaver, John L.; Paquet, Paul C.; Ruggiero, Leonard F. 1996. Resilience and Conservation of Large Carnivores in the Rocky Mountains. Conservation Biology; 10 (4): 964-976.
Waits, Lisette. Using DNA to Monitor Bear Populations in Glacier National Park. Unpublished proposal. University of Idaho, Moscow, ID.
Weatherhead, P.J. 1986. How unusual are unusual events? American Naturalist. 128: 150-154.
Williams, J.S. 1992. Population characteristics and habitat use of mountain lions in the Sun River area of northern Montana. M.S. Thesis, Montana State University, Bozeman, MT. 109p.
Wright, R. G. 1990. An index bibliography of wildlife of wildlife research in the U. S. National Parks. NPS Technical Report NPS/NRUI/NRTR-90/05.
Wright, R.G. 1996 Wolf and Moose Populations in Isle Royale National Park Pages 74-95 *in* Halvorson, W.L.;Davis, G.E.eds. Ecosystem Management in the National Parks. University of Arizona, Tucson, AZ.
Wright, R.G. 1999. Wildlife management in the national parks: questions in search of answers. Ecological Applications 9(1): 30-36.
Young, S.P. 1946. History, life habits, economic status, and control, Part 1. Pages 1-173 *in* Young, S.P.; Goldman, E.A. The puma, mysterious cat. The American Wildlife Institute, Washington, D.C. 358p.
Zar, Jerold H. 1996. Biostatistical Analysis. Upper Saddle River, N.J.:Prentice Hall. 662p.
Zielinski, William; Gill, Connie. 1997. A Sensitive Measure of Forest Ecosystem Health. U.S. Department of Agriculture, Forest Service. Forestry Research West. July: 17-24.
Zielinski, William; Kucera, Thomas E. 1995. Lynx, Wolverines, Fishers, and Martens: Survey Methods for Their Detection. U.S. Department of Agriculture, Pacific Southwest Research Station Forest Service, General Technical Report 157.

2. Wilderness and Ecosystems



Studies in the Wilderness Areas of the Kenai National Wildlife Refuge: Fire, Bark Beetles, Human Development, and Climate Change

Edward E. Berg

Abstract—Wilderness areas comprise 65% of the 1.92 million acre Kenai National Wildlife Refuge, Alaska. Fire history studies indicate that fire frequency increased substantially in both white and black spruce forests after European settlement. Dendrochronolgy studies indicate that regional-scale spruce bark beetle outbreaks occurred in the 1820s, 1880s, and 1970s. None of these outbreaks was as intense as the 1990s outbreak, which has killed most of the large white and Sitka/Lutz spruce on the southern Kenai Peninsula. Strong climatic warming appears to have accelerated the recent outbreak, probably through drought-stress of large trees. Logging of once-remote beetle-killed forests on private lands on the southwestern flank of the Refuge is shrinking available brown bear habitat and making protection of the wilderness areas more crucial.

The Kenai National Wildlife Refuge is the most popular and most heavily visited of Alaska's sixteen National Wildlife Refuges. It lies on the highway system within a two to three hour drive of Anchorage, and is a popular recreation destination for hunting, fishing, skiing and snow machining. The Refuge was established in 1941 by President Roosevelt as the Kenai National Moose Range, in response to hunting and conservation organizations seeking to preserve the so-called "giant Kenai moose," then considered a separate subspecies of moose. The name was changed from "Moose Range" to "Wildlife Refuge" in 1980 under the Alaska National Interest Lands Conservation Act (ANILCA), and more territory was added to bring the acreage up to ~2 million acres. ANILCA also established the wilderness areas of the Kenai NWR (fig. 1).

Thirty-five percent of the Refuge is more or less road accessible and is not classified as wilderness. The remaining 65% (1.3 million acres) is accessible only by foot, horseback, boat, snowmachine or plane and is classified as wilderness. Snowmachine use is allowed in the wilderness areas below treeline, and outside of certain special set-aside areas, such as the Canoe System which is reserved for dogmushers and skiers. Floatplane landings are permitted on a small number of lakes in the wilderness areas, and limited helicopter landings are allowed for scientific purposes.

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Practically speaking, only a tiny fraction of the Kenai Peninsula's residents and tourists ever get back into the wilderness areas, so direct human impact is fairly low in these areas. The general proximity of the wilderness areas to urban centers, however, makes them excellent candidates for field studies that require large areas of land with relatively minor human impact. Animals with large home ranges, such as wolves and brown bears, can be studied here over a period of years or decades, as can ecological and climatic processes that affect animal populations and their habitats on landscape and regional scales.

Even though the wilderness areas are large and relatively isolated from the road system, this does not mean that they are timeless and unchanging, or unimpacted by human activity on adjoining lands. In my six years as the Refuge ecologist much of my work has focused on documenting the long-term changes in these wilderness areas, specifically as regards fire, spruce bark beetles and climate change.

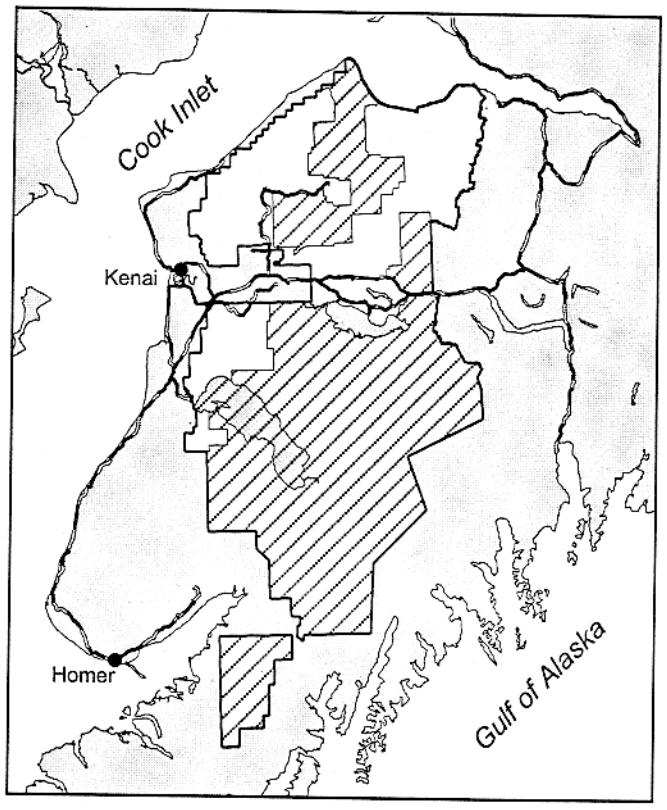

Figure 1—Map of the Kenai National Wildlife Refuge. Wilderness areas are shown with dotted lines.

Fire

In the 20th century, the Refuge has experienced many small fires and two large fires, most of which have been human-caused. Unlike Interior Alaska the Kenai Peninsula experiences very little lightening, so we have been curious to know whether fire was common before European settlement in mid-19th century. We have addressed this with separate fire history studies in white spruce and black spruce, and with charcoal studies in lake sediments.

The white spruce study examined mature white spruce forests using age-class analysis. We found nine "even-aged" polygons (homogeneous stands) with an initial cohort of recruits formed after a disturbance (presumably fire), with dates from the 1830s to the early 1900s. We found 11 older polygons with broad age distributions, indicative of continuous gap-phase recruitment. Virtually every stand had charcoal fragments in the soil, indicating that the stand had burned at least once in the 9,000 years that spruce forests have existed on the central Kenai since deglaciation (Ager 1983, S. Anderson, pers. comm. 1999).

In the black spruce study, Andrew DeVolder used tree-rings to cross-date burn poles and fire scars within the 310,000-acre 1947 burn. He dated 12 fires in the period 1708 to 1898; nine of these fires occurred after 1828, suggesting a substantial acceleration in fire frequency associated with European settlement (DeVolder 1999).

The lake sediment studies turned up remarkably little charcoal. A pulse of charcoal from the 1947 burn was visible in two sediment cores, but no other distinct peaks appeared in the ~1,000 years represented in the sediment cores. The level of background charcoal in the sediments was considered to be an order of magnitude less than that of a typical boreal forest lake in Interior Alaska, according to Jason Lynch and Jim Clark of Duke University (pers. comm.).

In the summer of 1998, Scott Anderson of Northern Arizona University pulled a 9 m core from one of our deeper lakes. This core has a bottom date of 13,170 years in glacial mud. The pollen has been analyzed at 10 cm intervals, and provides a full record of the revegetation history of the Kenai lowlands since deglaciation. Anderson is also doing a centimeter-by-centimeter measurement of the charcoal abundance in the upper layers to confirm or deny that presettlement fire frequency was as low as our earlier studies suggest. Thirty-nine tephra (volcanic ash) layers in the core are being analyzed by microprobe by Jim Beget of the University of Alaska - Fairbanks. This should provide the longest tephra chronology for eastern Cook Inlet and will be a valuable tool for dating a variety of stratified deposits in the region.

Spruce Bark Beetles

In the 1990s the white and Sitka/Lutz spruce forests of the Kenai Peninsula have been severely damaged by a record outbreak of the spruce bark beetle (*Dendroctonous rufipennis* Kirby), with red-needle acreage peaking at ~480,000 acres in 1996 (fig. 2). We have used dendrochronology to examine 13 stands throughout the peninsula for evidence of earlier outbreaks, using analysis of stand-wide growth releases. That is, when a stand is thinned by mortality of the overstory trees, the suppressed understory trees are released from

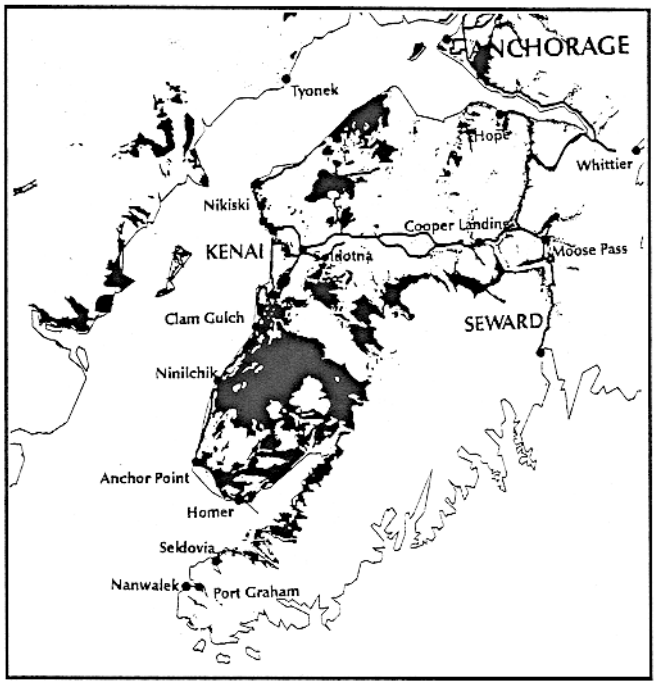

Figure 2—Spruce bark beetle red-needle acreage 1989-1997 (USDA Forest Service, State and Private Forestry annual surveys).

competition, and their annual growth rings become wider. This growth pulse typically lasts for about 70 to 90 years until the canopy closes and competition again intensifies. To detect growth pulses we measure the annual rings to 0.01mm accuracy and look for a doubling of the forward 10-year mean ring-widths over the previous 10-year mean. If the ratio of these means exceeds 2.0, we call this a release and graph the number of releases in an entire stand to get a picture of the thinning history of the stand (figs. 3 and 4).

When a number of stands are graphed together, we can see the regional pattern of thinnings (figs. 5 and 6). This approach reveals that the white and Sitka/Lutz spruce forests

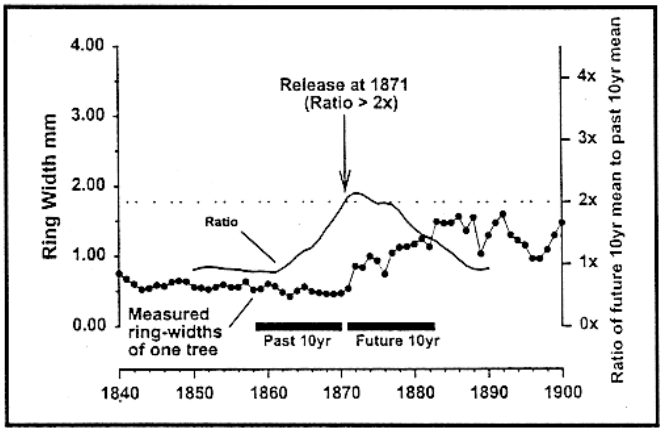

Figure 3—Definition of a release as a doubling (2x) of 10 year mean ring widths.

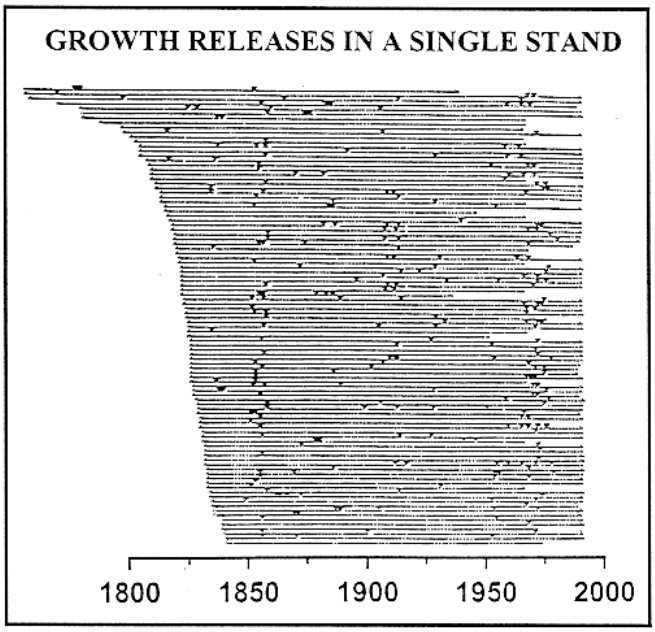

Figure 4—Release patterns in a very mature white spruce - birch stand. Each line represents a separate tree, with releases shown as black triangles. Many trees died in the 1970s, and most survivors released. Earlier releases can be seen in the 1850s and 1920s. (Graphic by C. Fastie).

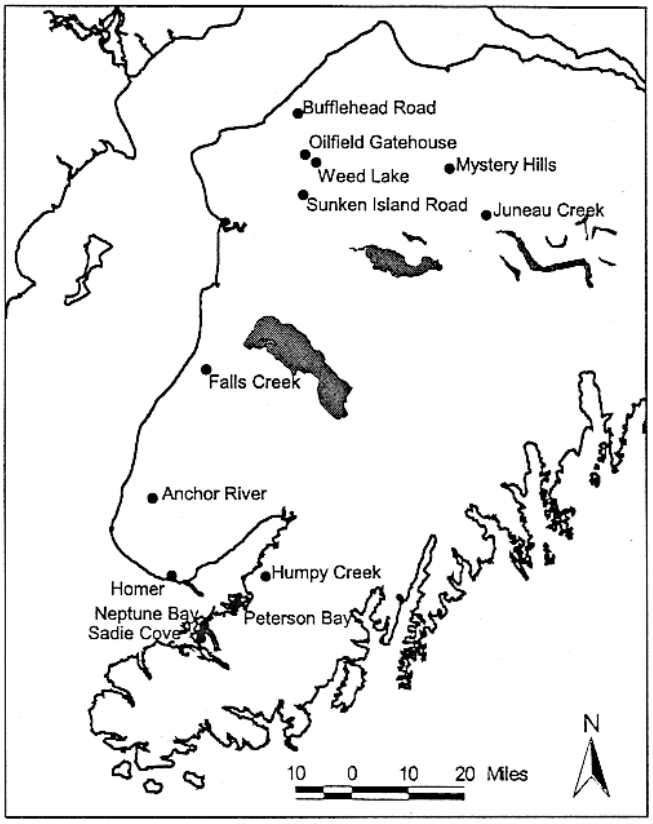

Figure 5—White and Sitka/Lutz spruce study sites for spruce bark beetle history.

on the Kenai have indeed experienced regional episodes of thinning: in the 1820s over most of the peninsula, in the 1880s in the southern peninsula, and in the 1970s in the central and northern peninsula. In some stands, we can see as many as three episodes of thinning, indicating persistent low levels of beetle infestation with periodic flare-ups. Even so, in most cases, the magnitudes of the past outbreaks are well below the magnitude of the present outbreak (Fastie and others, in review).

In earlier beetle outbreaks, Kenai Peninsula spruce forests recovered beetle-killed basal area within a few decades, either through released growth of survivors or through seedling recruitment; stand composition probably remained essentially unchanged (Fastie and others, in review). In the present outbreak, however, some stands lack adequate advanced regeneration (i.e., suppressed understory individuals), perhaps because of previous thinnings and releases. The death of mature overstory in these stands will mean the loss of seed sources for seedling regeneration. In mixed stands, this will mean a shift to more hardwood and less spruce; in pure spruce stands, we expect that heavy grass [*Calamagrostis canadensis* (Michx.) Beauv.] will dominate local sites for many decades. Some foresters have predicted that the Kenai Peninsula will become a "spruce savannah," at least in the upland areas, but our studies of past beetle outbreaks show that on a scale of decades, white and Sitka/Lutz spruce stands have a remarkable capacity to perpetuate themselves, both through release and seedling regeneration, and we don't subscribe to the spruce savannah prediction.

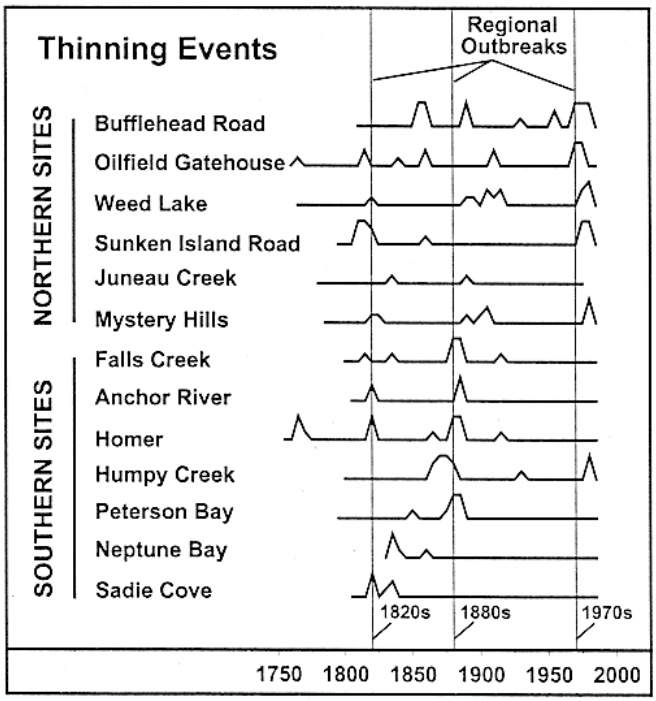

Figure 6—Summary of release pulses and inferred spruce bark beetle outbreaks in white and Sitka/Lutz spruce. High peaks are significant at $p<0.001$, medium peaks at $p<0.01$, small peaks at $p<0.05$.

Human Development

The population of the Kenai Peninsula has increased at an annual rate of 2.2% in recent years. The impact of this increase is felt most heavily on the non-wilderness parts of the Refuge because of the good road access to popular fishing spots, moose hunting and campgrounds. The presence of the recreational infrastructure serves as an extremely valuable buffer for the wilderness areas. The most serious impact of off-Refuge development, so far, is the extensive network of logging roads initiated by the spruce bark beetle outbreak. The beetle outbreak has greatly accelerated timber harvest on private lands, as owners race to extract value before the trees rot on the stump. Chronic heartrot and beetle-borne blue stain fungus set time limits of several years on saw timber from beetle-killed trees, and much of the harvest is now simply being chipped for pulp. Approximately 85,000 acres have been harvested on the western Kenai since 1990, according to Alaska Department of Fish and Game, Habitat Division.

Extensive logging has occurred on Native corporation lands on the southwestern side of the Refuge right up to the wilderness boundary. The logging roads are considered permanent because the Native corporations wants access to the land for their members' use and for income generated by sales or leases of recreational property. In the past, this area was remote undeveloped land that served as a buffer for brown bear habitat in the wilderness areas. The brown bear population numbers 250 to 300 individuals and is considered the most sensitive species on the Kenai. Brown bears are our "canary" in the coal mine. The increasing human population is raising the number of "defense of life and property" killings of brown bears to five to seven per year; these killings have severely limited the number of legally harvestable bears to about seven per year. Brown bears roam over large areas, and there is concern that their numbers should not fall below a threshold level from which they could not recover. Loss of habitat, regardless of ownership or land classification, is bad for bears, and the new logging roads definitely reduce the suitability of many square miles of bear habitat on the Kenai Peninsula.

Climate Change

The Kenai Peninsula, and indeed much of Alaska, has been warming up, probably at an accelerating rate. The Kenai airport shows a 2.9°F/50 years increase in mean annual temperature since the mid-1940s, and the Homer airport shows a 3.9°F/50 years increase in the same period. Much of this increase occurs in warmer Decembers (~9°F/50 years) and Januarys (~7°F/50 years), but summer temperatures are up 2.5°F/50 years in Kenai and 4.1°F/50 years in Homer., according to National Weather Service records. These are extremely strong gradients. We used tree-rings to reconstruct summer temperatures back to 1706 and found a general rise of about 3°F in summer temperature at treeline from a low in the 1810s (DeVolder 1999).

The effects of this warming are multifold. Glaciers are retreating rapidly (Wiles and Calkin, 1994), treeline is rising and water tables are falling as the landscape dries. Precipitation is highly variable on the Kenai, and it appears that the drying phenomenon is primarily due to increased evapotranspiration associated with the warming. We see black spruce invasion of wetland perimeters due to gradual lowering of the water table. Many kettle ponds that held water in 1950 are now grassy pans with spruce and willow invasion. These ponds are important breeding habitat for wood frogs, our only amphibian species.

The warming trend, and more specifically its attendant droughtiness, appear to have triggered the present spruce bark beetle outbreak. There are two direct temperature effects for the beetles, in that they need 60°F days in the spring to make their reproductive flight to new trees, and they can complete their normal two-year life cycle in one year during a long warm summer. Probably more important, however, is the secondary effect of temperature in creating drought-stressed trees. The beetles have evolved to attack the trees during the period of maximum drought stress in the spring, when the stomata are open on sunny days but the soil is still frozen and water uptake is retarded. Many large spruce show decreasing ring-widths over recent decades, partly due to canopy closure, but also due to the increased growing season droughtiness. This decreased annual growth in mature trees increases their susceptibility to beetle attack (Hard 1985, 1987).

Wilderness as a Laboratory

The Kenai NWR has "research and education" written into its statement of purpose, and the wilderness areas of the Refuge are indeed used for scientific research, as the above studies indicate. Wildlife monitoring flights are perhaps our most frequent visitation of the wilderness areas. We have acquired more than 12,000 radiocollar locations for lynx, marten, wolves, caribou, moose, trumpeter swans, bald eagles and bears since 1976, in both wilderness and non-wilderness habitats. We are assembling a vegetation GIS layer with which we hope to model wildlife habitat use and habitat change, propagation of wildfires and bark beetles outbreaks, and vegetation succession in response to disturbance of various kinds. This kind of data-intensive modeling requires considerable ground-truthing, and we deploy crews of seasonal technicians, graduate students and volunteers every summer to gather as much data as possible in our all-too-brief field season from May to mid-September.

Much of this work is done in the Wilderness areas, and it does create a certain level of human presence in these areas. The human presence intensifies in August when the moose and caribou hunters arrive. Even so, both scientific and hunting visitation is rather tightly controlled by Refuge managers through a permit system, and visitation could be scaled back if we judged the impacts to be significant. Snowmachine use in the winter, however, is not controlled by permits, and it could become a major problem if the present popularity of snowmachining on the Kenai Peninsula continues to accelerate. Snowmachine use in the Refuge Wilderness areas is allowed under a "traditional use" provision of ANILCA, and it is unlikely that Congress would revoke this provision in any foreseeable future.

Conclusions

The landscape of the Kenai NWR and its wilderness areas has changed substantially over the past 150 years. Human settlers and their fires have created more early successional hardwood vegetation and brought more moose into the forests. Climate warming is pushing back the glaciers, raising treelines and drying our wetlands. Bark beetles are hitting the spruce forests harder than they did in the past, and our previously undeveloped buffer zone on private land has been turned into a checkerboard of clearcuts. One can lament these changes, but the good news is that they provide a wonderful opportunity for an unlimited variety of ecological studies. We try to take full advantage of this opportunity, and we always invite interested researchers to contact us with proposals. Many graduate thesis studies have been done on the Refuge, because we have been able to provide logistical and financial support.

Acknowledgments

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References

Ager, T. A. 1983. Holocene vegetational history of Alaska. In: Wright, Jr., H. E., ed. Late Quaternary Environments of the United States, Vol. 2, The Holocene, 128-141.

DeVolder, A. D. 1999. Fire and climate history of lowland black spruce forests, Kenai National Wildlife Refuge, Alaska. MS Thesis, Northern Arizona University, Flagstaff AZ.

Fastie, C. L.; Berg, E. E.; Swetnam, T. W. 1999. The response of boreal forests to lethal outbreaks of spruce bark beetles on the Kenai Peninsula, Alaska. (in review).

Hard, J. S. 1985. Spruce beetles attack slowly growing spruce. Forest Science 31:839-850.

Hard, J. S. 1987. Vulnerability of white spruce with slowly expanding lower boles on dry, cold sites to early seasonal attack by spruce beetle in south central Alaska. Canadian Journal of Forest Research 17:428-435.

Wiles, G. C., and P. E. Calkin. 1994. Late Holocene, high-resolution glacial chronologies and climate, Kenai Mountains, Alaska. Geological Society of America Bulletin 106:281-303.

Does Protection of Desert Tortoise Habitat Generate Other Ecological Benefits in the Mojave Desert?

Matthew L. Brooks

Abstract—This paper summarizes the ecological effects of fenced habitat protection for the desert tortoise (*Gopherus agassizii*) at the Desert Tortoise Research Natural Area in the Mojave Desert. The following were higher inside than outside the natural area: (1) annual and perennial plant biomass, cover, diversity and dominance by natives, (2) soil seed biomass, (3) nocturnal rodent density and diversity, (4) breeding bird abundance and species richness, and (5) lizard abundance and species richness. The following were higher outside the natural area: (1) biomass of alien annual plants, and (2) abundance of black-tailed hares (*Lepus californicus*). Protection of habitat for the desert tortoise has resulted in higher abundance and diversity of many types of native plants and animals at this site.

Recovery plans for threatened or endangered species often require protection of very large areas from disturbances that threaten the species. Conservation biologists generally agree that these protected areas provide ecological benefits that extend far beyond the individual species for which they were created (Hudson 1991; Noss 1992). Benefits can range from the promotion of biodiversity to the maintenance of watershed functions. Although protection of habitat appears to be one of the most effective ways to preserve multiple levels of biological organization (Noss and Harris 1986; Falk 1991; Bloomgarden 1995), these effects are rarely documented and the general public remains largely unaware of them. This becomes a significant problem on public lands when the target species' population declines despite protection, and public land managers are pressured to reestablish multiple land-use activities.

Large areas of desert in southwestern North America are currently managed to protect the desert tortoise (*Gopherus agassizii*) and its habitat. In response to widespread population declines across its range, the desert tortoise was listed as a threatened species in 1990 in the Mojave and Colorado Deserts of California, Nevada, Arizona and Utah, west and north of the Colorado River (Fish and Wildlife Service 1990). The Desert Tortoise (Mojave Population) Recovery Plan proposed 14 Desert Wildlife Management Areas where local desert tortoise populations could be managed for recovery. (Fish and Wildlife Service 1994a). Criteria for the design of these management areas followed theory that was current during the early 1990s, and guidelines were established to determine their boundaries (Fish and Wildlife Service 1994a): (1) reserves should be distributed across the native range of the desert tortoise rather than confined to a small portion of the range; (2) large reserves are better than small reserves; (3) contiguous habitat is better than fragmented habitat; (4) habitat patches with less edge-to-area ratios are better than those with more; (5) closely spaced habitat patches are better than those spread far apart; (6) interconnected habitat patches are better than isolated patches; and (7) roadless habitat isolated from humans is better than habitat with roads and accessible to humans. These guidelines were used to establish areas of critical habitat for the desert tortoise in 1994, ranging from 221 to 4,130 km^2 each (Fish and Wildlife Service 1994b). This critical habitat (26,087 km^2), plus habitat already protected at Joshua Tree National Park (2,574 km^2) and at the Desert Tortoise Research Natural Area (DTNA) (100 km^2), total 28,761 km^2 of land protected for the desert tortoise (Berry 1997).

Critical habitat for the desert tortoise is managed to minimize the many threats to this species, most of which are related to human activities (Fish and Wildlife Service 1994a). These threats are summarized in a review of the Desert Tortoise (Mojave Population) Recovery Plan (Berry 1997). Despite habitat protection, densities of desert tortoises have continued to decline, primarily due to disease and predation of juveniles by ravens (Berry and others 1990a; Berry and others 1990b; Berry 1996). Protection of habitat may be insufficient to completely prevent the current decline in desert tortoise populations, but it is necessary for the ultimate recovery of the species.

Protection of desert tortoise habitat appears to also have other ecological benefits, and major bioregional ecosystem management plans have adopted the desert tortoise as an umbrella species for the conservation of many other taxa. This strategy assumes that habitat protection for an umbrella species will have multiple ecological benefits for sympatric populations, communities, or ecosystem components (Caro and O'Doherty 1999). Accordingly, the network of areas protected for the desert tortoise is assumed to have a wide range of other ecological benefits. Although the concept of the umbrella species is widely used, its effectiveness has not been empirically tested.

The DTNA, established in 1973, is the oldest area providing protection for the desert tortoise. Its boundaries were chosen to encompass a wide range of landforms, soils, elevations, and plant communities, all habitat factors that were considered important to the viability of the resident desert tortoises. The DTNA represents only a small fraction of the

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land protected for the desert tortoise, thus only a small fraction of the total effect of the desert tortoise as an umbrella species can be evaluated at this site. However, the DTNA provides an opportunity to test the hypothesis that abundance and diversity of native plants and animals are higher inside than outside of protected desert tortoise habitat. In this paper I use empirical data from published studies to evaluate the effects of habitat protection on a variety of plant and animal taxa at this site.

Site Description

The DTNA is located in the Fremont Valley and Rand Mountains of the western Mojave Desert, near California City, Kern County, California. The average annual rainfall for this region is 157 mm, 83% occurring between November and April. Mid-summer temperatures range from an average low of 19 °C to an average high of 34 °C, and mid-winter temperature averages in December range from 0 °C to 7 °C (National Oceanographic and Atmospheric Administration 1994). The woody plant community is dominated by creosote bush (*Larrea tridentata*) and burrobush (*Ambrosia dumosa*), with locally abundant patches of goldenhead (*Acamptopappus sphaerocephalus*), saltbush (*Atriplex polycarpa*), mormon tea (*Ephedra nevadensis*), goldenbush (*Ericameria cooperi*), California buckwheat (*Eriogonum fasciculatum*), cheesebush (*Hymenoclea salsola*), boxthorn (*Lycium andersonii*), Fremont dalea (*Psorothamnus fremontii*), cotton-thorn (*Tetradymia stenolepsis*), Joshua tree (*Yucca brevifolia*) and Mojave aster (*Xylorhiza tortifolia*) (Brooks 1995; Brooks 1999) Perennial grasses include Indian ricegrass (*Achnatherum hymenoides*) and desert needlegrass (*Achnatherum speciosum*), and small populations of bluegrass (*Poa secunda*). Cacti include small numbers of silver cholla (*Opuntia echinocarpa*) and beavertail cactus (*Opuntia basilaris*).

The western Mojave Desert was one of the first and most intensely used rangelands in the deserts of California (Bureau of Land Management 1980; Bureau of Land Management 1993). Extensive cattle grazing ceased in the 1930s, but sheep grazing continues to the present day. Recreational use of off-highway vehicles has been prevalent since the 1960s (Bureau of Land Management 1973). Since its creation in 1973, the DTNA has been closed to sheep grazing and vehicle travel has been limited to existing roads. Similar restrictions exist in other areas of critical habitat for the desert tortoise (Fish and Wildlife Service 1994a). Effective protection from trespass began in 1979-1980, when a 1 m tall fence of 15 x 15 cm "hogwire" hardware cloth was constructed along the perimeter. Trespass by sheep or off-road vehicles declined notably after this fence was constructed (Berry, personal communication). Sheep grazing and unrestricted off-highway vehicle use have continued in most areas adjacent to the DTNA, especially on private lands. The number of visitors to the DTNA increased steadily from 2,500 in 1982 to 8,000 in 1988 (Bureau of Land Management and California Department of Fish and Game 1988), but visitor use is largely confined to a small area near the interpretive center, more than 3 km from any of the study sites that I describe in this paper. Further descriptions of the disturbance history at the DTNA can be found in Brooks (1995; 1999).

Effects of Protection at the DTNA

This section summarizes a series of studies that measured differences in population and community variables of plants and animals inside and outside the DTNA. Study sites ranged from the northeast to the southwest parts of the DTNA and consisted of paired plots inside and outside the fenceline. Plots were matched for slope, aspect, elevation, soil type, and vegetation type and were located 400 to 1,000 m inside or outside the fenceline. The results are organized by taxa, and brief descriptions of methodologies are provided for each. Significance tests are identified in the tables, and statistical significance is reported at three levels, P - 0.10, 0.05, and 0.01. I sacrificed detail to maximize succinctness and clarity of the results. Detailed descriptions of these studies are contained in Brooks (1992; 1995; 1998; 1999).

Annual Plants

Aboveground live biomass and species richness of annual plants were measured at two sites during April 1990, 1991, and 1992 (Brooks 1992; Brooks 1995). When annual plants reached peak biomass and most species were flowering all annual plants within replicate 10 x 20 cm frames were cut at ground level, sorted by species, dried to a constant biomass at 60°C and weighed.

More species of annual plants had higher biomass (g/200 cm^2) inside than outside the DTNA during each year (table 1). Biomass of goldfields (*Lasthenia californica*) and comb-bur (*Pectocarya* spp.) were significantly higher inside in 1990, small-flowered poppy (*Eschscholzia minutiflora*) and goldfields were higher inside in 1991, and fiddleneck (*Amsinckia tessellata*), Mojave suncup (*Camissonia campestris*) and lacy phacelia (*Phacelia tanacetifolia*) were higher inside in 1992. The only species with higher biomass outside was the alien Mediterranean grass (*Schismus* spp.) during each of the three years. The biomass ratio of forbs to alien annual grasses was much higher inside than outside the DTNA (table 2), indicating that alien grasses were less dominant in the protected area. Species richness of annual plants was also higher inside than outside during each year, but differences were not statistically significant (table 1).

The difference in total annual plant biomass was very high inside versus outside the DTNA, but high inter-sample variance and conservative statistics limited levels of significance. For example, in 1990, aboveground live biomass (dry g/ha) was 12,325 inside and 4,740 outside (P = 0.22); in 1991, biomass was 199,460 inside and 57,770 outside (P = 0.17); and in 1992, biomass was 94,920 inside and 39,610 outside (P = 0.01).

Annual plants were sampled at five additional sites during 1994 and 1995 to determine the dominance of alien annual plants inside versus outside the DTNA (Brooks 1998). When annual plants reached peak biomass all annual plants within replicate 25 x 50 cm frames were cut at ground level, sorted by species, dried to a constant biomass at 60°C, and weighed. Biomasses and species richness of aliens were generally higher outside the DTNA, but results varied between years, and significance levels were weak (table 3).

Table 1—Annual plant biomass and species richness inside compared to outside the DTNA, April 1990-1992 (Brooks 1992, 1995).

	1990	1991	1992
Number of species with higher biomass inside[a]	5 of 6	17 of 18***	15 of 17***
Species with significantly higher biomass inside[b]	goldfields** (*Lasthenia californica*) comb-bur (*Pectocarya* spp.)	small-flowered poppy* (*Eschscholzia minutiflora*) goldfields**	fiddleneck*** (*Amsinckia tessellata*) Mojave suncups** (*Camissonia campestris*) lacy phacelia (*Phacelia tanacetifolia*)*
Species with significantly higher biomass outside	Mediterranean grass*‡ (*Schismus* spp.)	Mediterranean grass*‡	Mediterranean grass*‡
Species richness	higher inside	higher inside	higher inside

[a]Sign test
[b]Two-tailed paired *t* test
*P - 0.10, **P - 0.05, ***P - 0.01
‡Alien species

Perennial Shrubs

Density and cover of perennial shrubs were measured at two sites in June 1990 (Brooks 1992; 1995), and cover, height, volume and diversity were measured at two additional sites in June 1995 (Brooks 1999) using the point-quarter method (Greig-Smith 1964). Density of perennial shrubs was generally unaffected by protection, whereas cover and diversity were higher in the protected area (table 4). Estimates of cover were 33% (Brooks 1995) and 50% (Brooks 1999) higher inside than outside the DTNA. Cover of burrobush, California buckwheat, boxthorn and Fremont dalea were significantly higher in protected areas. Because cover was higher and density was generally unaffected by protection, the average size of individual shrubs was higher inside the DTNA. In an extreme case, Fremont dalea had higher density outside, but higher cover inside, indicating that individuals were much larger inside than outside the DTNA. Height diversity, cover diversity and volume diversity of perennial shrubs were all unaffected by protection (Brooks 1999). Species diversity was higher inside, but differences were either marginally significant (P - 0.10, table 4, Brooks 1995) or nonsignificant (Brooks 1999).

Soil Seed Biomass

Soil seedbank biomass was measured at two sites in April 1990, 1991 and 1992 (Brooks 1992; 1995). Samples were 6 cm diameter x 2 cm deep and consisted of both annual and perennial species. Biomass was higher inside than outside the DTNA during each year, but high inter-sample variance limited levels of significance (table 5).

Nocturnal Rodents

Nocturnal rodents were trapped at two sites on five occasions between March 1990 and February 1992 (6144 trap nights) (Brooks 1992; Brooks 1995). An 8 x 8 grid of Sherman live traps placed 10 m apart was used at each of the four paired plots. Animals were trapped four to six consecutive nights during the new moon to produce mark-recapture density and diversity estimates. Density of nocturnal rodents was higher inside than outside the DTNA, especially for the long-tailed pocket mouse (*Chaetodipus formosus*), Merriam's kangaroo rat (*Dipodomys merriami*) and southern grasshopper mouse (*Onychomys torridus*) (table 6). No species was more abundant in the unprotected areas. Species richness, evenness and the Shannon-Wiener diversity index were also significantly higher inside.

Table 2—Ratio of forbs to annual grasses inside and outside the DTNA, April 1990-1992 (Brooks 1992, 1995).

	1990	1991	1992
Inside the DTNA[a]	1,232**	34**	18**
Outside the DTNA	259	13	4**

[a]two-tailed paired *t* test of the difference between forb and grass biomass
**P - 0.05

Table 3—Biomass and species richness of alien annual plants inside compared to outside the DTNA, April 1994 and 1995 (Brooks 1998). The area where each was highest is indicated for each year.

	1994[a]	1995
Red brome (*Bromus madritensis* ssp. *rubens*)	inside	outside**
Chilean chess (*Bromus trinii*)	outside	inside
Mediterranean grass (*Schismus* spp.)	outside*	outside
Filaree (*Erodium cicutarium*)	outside	inside
Total alien biomass	outside**	outside
Alien species richness	outside	outside

[a]Fisher's protected LSD test.
*P - 0.10, ** P - 0.05

Table 4—Perennial shrub cover, density, and diversity inside compared to outside the DTNA, June 1990 (Brooks 1992, 1995).

	Cover	Density
Number of species higher inside[a]	11 of 13***	7 of 13
Total perennial shrubs[b]	higher inside	higher inside
Species significantly higher inside	burrobush** (*Ambrosia dumosa*)	none
	California buckwheat* (*Eriogonum fasciculatum*)	
	boxthorn* (*Lycium andersonii*)	
	Fremont dalea* (*Psorothamnus fremontii*)	
Species significantly higher outside	none	Fremont dalea**
	Diversity	
Species richness	higher inside	
Evenness	higher inside*	
Shannon-Wiener index	higher inside*	

[a]Sign test
[b]Two-tailed paired *t* test
*P - 0.10, ** P - 0.05, *** P - 0.01

Table 5—Soil seed bank biomass inside compared to outside the DTNA, April 1990-1992 (Brooks 1992, 1995).

	1990	1991	1992
Seed biomass[a]	higher inside	higher inside*	higher inside**

[a]Two-tailed paired *t* test
* P - 0.10, ** P - 0.05

Table 6—Nocturnal rodent densities and diversity inside compared to outside the DTNA, 1990-1992 (Brooks 1992, 1995).

	Density
Number of species higher inside[a]	4 of 5
Total nocturnal rodents[b]	higher inside*
Species significantly higher inside	long-tailed pocket mouse*** (*Chaetodipus formosus*)
	Merriam's kangaroo rat** (*Dipodomys merriami*)
	southern grasshopper mouse** (*Onychomys torridus*)
Species significantly higher outside	none
	Diversity
Species richness	higher inside***
Evenness	higher inside***
Shannon-Wiener index	higher inside***

[a]Sign test
[b]Two-tailed paired *t* test
*P - 0.10, ** P - 0.05, *** P - 0.01

Table 7—Bird abundance and species richness inside compared to outside the DTNA during breeding and wintering seasons, 1994-1996 (Brooks 1999).

	Breeding season	Wintering season
Abundance[a]	higher inside***	higher inside
Species richness	higher inside***	higher inside
Species significantly higher inside	sage sparrow*** (*Amphispiza belli*)	none
	verdin** (*Auriparus flaviceps*)	
	cactus wren* (*Campylorhynchus bunneicapillus)*	
	ash-throated flycatcher** (*Myiarchus cinerascens*)	
	LeConte's thrasher *** (*Toxostoma lecontei*)	
	loggerhead shrike* (*Lanius ludovicianus*)	
Species significantly higher outside	none	none

[a]Analysis of variance
*P - 0.10, ** P - 0.05, *** P - 0.01

Table 8—Lizard abundance and species richness inside compared to outside the DTNA, 1994-1995 (Brooks 1999).

Abundance[a]	higher inside***
Species richness	higher inside*
Species significantly higher inside	western whiptail*** (*Cnemidophorous tigris*) desert spiny* (*Sceloporous magister*)
Species significantly higher outside	none

[a]analysis of variance
*P - 0.10, *** P - 0.01

Table 9—Black-tailed hare (*Lepus californicus*) abundance inside compared to outside the DTNA, 1994-1995 (Brooks 1999).

Transect observations[a]	higher outside**
Fecal pellet counts[b]	higher outside***

[a]Analysis of variance
[b]Mann-Whitney U test
** P - 0.05, *** P - 0.01

Birds

Birds were censused at two sites on six occasions between May 1994 and January 1996 (Brooks 1999). A 4 x 4 grid of point-count stations placed 400 m apart was used at each of the four paired plots. Birds were censused for 2.5 h after sunrise during spring and winter seasons. Abundance and species richness of birds were higher inside than outside the DTNA, but differences were only significant during the spring breeding season (table 7). Sage sparrow (*Amphispiza belli*), verdin (*Auriparus flaviceps*), cactus wren (*Campylorhynchus bunneicapillus*), ash-throated flycatcher (*Myiarchus cinerascens*), loggerhead shrike (*Lanius ludovicianus*) and LeConte's thrasher (*Toxostoma lecontei*) were all significantly more abundant inside the DTNA during the breeding season. No species was more abundant in the unprotected areas.

Lizards

Lizards were censused at two sites on three occasions between July 1994 and July 1995 (Brooks 1999). Lizards were counted along six 1200 m parallel transects placed 400 m apart at each of the four paired plots. Censuses were conducted from 09:00 to 11:00 h PST. Abundance and species richness of lizards were higher inside than outside the DTNA (table 8). Western whiptail (*Cnemidophorous tigris*) and desert spiny (*Sceloporous magister*) lizards were significantly more abundant inside the DTNA, and no species was more abundant in the unprotected areas.

Black-Tailed Hares

Abundance of the black-tailed hare (*Lepus californicus*) was estimated using transect counts at two sites in May and July 1994 and using counts of fecal pellets at five other sites in April 1994 and 1995 (Brooks 1999). Individuals were counted along 1,200 m transects, and fecal pellets were counted within 25 x 50 cm sampling frames. Both methods indicated that black-tailed hares were significantly more abundant in the unprotected areas outside the DTNA (table 9).

Discussion

These data support the hypothesis that abundance and diversity of native plants and animals are higher inside than outside of protected desert tortoise habitat. Results from the DTNA may apply in other areas of protected desert tortoise habitat, for a number of reasons. Although the DTNA (100 km^2) is much smaller than other areas protected for the desert tortoise (typically >1,000 km^2), it is much larger than the home ranges of the wildlife studied. Most of the organisms found at the DTNA are also found throughout the geographic range of the desert tortoise. Disturbance effects at the DNTA are typical of those found adjacent to protected desert tortoise habitat elsewhere in its range. However, additional studies are required at other protected areas throughout its geographic range to comprehensively evaluate the desert tortoise as an umbrella species.

The one factor that may distinguish the DTNA from most other protected areas is the existence of a fence around its perimeter. Only Joshua Tree National Park has a similar fence. Trespass of sheep and off-highway vehicles was significantly reduced after the fence was constructed at the DTNA (Berry, personal communication). Unauthorized sheep grazing and off-highway vehicle use often occur adjacent to the DTNA, despite signs prohibiting these activities. It is likely that enforcement of land use restrictions is less effective where fences do not exist. Fenced areas need to be compared to unfenced areas with similar land use restrictions to determine the effectiveness of fencing as a management tool.

Protection from human disturbances can affect plants and animals directly or indirectly. Direct effects of human disturbance can include biomass removal, direct mortality or the alteration of behavioral patterns. Indirect effects may involve direct changes in an ecosystem component that secondarily affects others. For example, shrub cover was significantly lower outside than inside the DTNA, and this difference was likely due to the direct removal or damage to shrubs by sheep and off-highway vehicles. This effect on habitat structure may have secondarily caused the lower abundance and diversity of rodents, birds and lizards outside the DTNA. The one species with higher abundance outside, the black-tailed hare, prefers open habitats with minimal cover (Burt and Grossenheider 1976; Sosa Burgos 1991). Another potential indirect effect of protection is the prevention of plant biomass removal and reduced seed set and the secondary effects that the reduction in seed bank biomass has on granivorous wildlife (Brooks 1995). Protection may also prevent plant biomass removal and higher order effects on herbivorous arthropods and insectivorous vertebrates, although these relationships remain untested (Brooks 1999).

Current conditions inside and outside the DTNA are the result of approximately 20 years of limited protection (since establishment in 1973) and 10 years of effective protection

(since fencing in 1980). Ecological differences between the protected and unprotected areas are likely due to both recovery from previous disturbance inside and further degradation from additional disturbance outside. In either case, protection of desert tortoise habitat has benefited a wide variety of plants and animals at this site.

References

Berry, K.H. Personal communication. Wildlife Ecologist. United States Department of the Interior, United States Geological Survey, Biological Resources Division, Western Ecological Research Center, Box Springs Field Station. 1990.

Berry, K. H. 1996. Demographic consequences of disease in two desert tortoise populations in California, USA. in J. Van Abbema editor Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles—An International Conference. Purchase, New York, USA.

Berry, K. H. 1997. The desert tortoise recovery plan: An ambitious effort to conserve biodiversity in the Mojave and Colorado Deserts of the United States. Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles – An International Conference, pp. 430-440. New York Turtle and Tortoise Society.

Berry, K. H., L. H. Nicholson, S. Juarez, and A. P. Woodman. 1990a. Changes in desert tortoise populations at four sites in California. Pages 60-80 Proceedings of the 1986 Desert Tortoise Council Symposium.

Berry, K. H., T. Shields, A. P. Woodman, T. Campbell, J. Roberson, K. Bohuski, and A. Karl. 1990b. Changes in desert tortoise populations at the Desert Tortoise Research Natural Area between 1979 and 1985. Pages 101-123 Proceedings of the 1986 Desert Tortoise Council Symposium.

Bloomgarden, C. A. 1995. Protecting endangered species under future climate change: from single-species preservation to an anticipatory approach. Environmental Management. 19:641-648.

Brooks, M. L. 1992. Ecological impact of human disturbance at the Desert Tortoise Natural Area, Kern County, California, 1978-1992. MA thesis, California State University, Fresno, California, USA.

Brooks, M. L. 1995. Benefits of protective fencing to plant and rodent communities of the western Mojave Desert, California. Environmental Management 19:65-74.

Brooks, M L. 1998. Ecology of a Biological Invasion: Alien Annual Plants in the Mojave Desert. Dissertation, University of California, Riverside. 186 pp.

Brooks, M L. 1999. Effects of Protective Fencing on Birds, Lizards, and Black-Tailed Hares in the Western Mojave Desert. Environmental Management 23:387-400.

Bureau of Land Management. 1973. Interim Critical Management Plan for Recreational Vehicle Use on the California Desert. United States Department of the Interior, Bureau of Land Management, California Desert Plan Program, Riverside, California, USA.

Bureau of Land Management. 1980. The California Desert Conservation Area Plan. United States Department of the Interior, Bureau of Land Management, Riverside, California.

Bureau of Land Management. 1993. Rand Mountains Fremont Valley Management Plan. United States Department of the Interior, Bureau of Land Management, Ridgecrest, California.

Bureau of Land Management and California Department of Fish and Game. 1988. A Sikes Act management plan for the Desert Tortoise Research Natural Area and Area of Critical Environmental Concern. United States Department of the Interior, Bureau of Land Management, California Desert District, Riverside, California.

Burt, W. H. and R.P. Grossenheider. 1976. Field Guide to the Mammals. Houghton Mifflin Company, Boston, USA.

Caro, T. M. and G. O'Doherty. 1999. On the use of surrogate species in conservation biology. Conservation Biology 13:805-814.

Falk, D. A. 1991. Joining biological and economic models for conserving plant genetic diversity. Pages 209-233. in D.A. Falk and K.E. Holsinger. Genetics and Conservation of Rare Plants. Oxford University Press, Oxford, England.

Fish and Wildlife Service. 1990. Endangered and threatened wildlife and plants; Determination of threatened status for the Mojave population of the desert tortoise. Federal Register 55(63):12178-12191.

Fish and Wildlife Service. 1994a. Desert tortoise (Mojave population) Recovery Plan. United States Department of the Interior, Fish and Wildlife Service, Portland, Oregon, USA.

Fish and Wildlife Service. 1994b. Endangered and threatened wildlife and plants; Determination of critical habitat for the Mojave population of the desert tortoise. Federal Register 59(26): 5820-5866.

Greig-Smith, P. 1964. Quantitative Plant Ecology, second edition. Butterworth, London, 246 pp.

Hudson, W. E. (ed.) 1991. Landscape Linkages and Biodiversity. Island Press, Washington, D.C.

National Oceanographic and Atmospheric Administration. 1994. Climatological Data Annual Summary, California, 1994. United States National Oceanic and Atmospheric Administration 98.

Noss, R. F. 1992. The wildlands project: Land conservation strategy. Wild Earth (Special Issue):10-25.

Noss, R. F. and L. D. Harris. 1986. Nodes, networks, and MUMS: preserving diversity at all scales. Environmental Management 10:299-309.

Sosa Burgos, L. M. 1991. Ecology of Two Coexisting populations of lagomorphs in the Mojave Desert, *Lepus californicus* and *Sylvilagus audobonii*. Dissertation, University of California, Los Angeles.

Ecosystem Dynamics and Disturbance in Mountain Wildernesses: Assessing Vulnerability of Natural Resources to Change

Daniel B. Fagre
David L. Peterson

Abstract—An integrated program of ecosystem modeling and extensive field studies at Glacier and Olympic National Parks has quantified many of the ecological processes affected by climatic variability and disturbance. Models have successfully estimated snow distribution, annual watershed discharge, and stream temperature variation based on seven years of monitoring. Various climatic scenarios were applied with the models to examine potential future wilderness conditions. This modeling indicates that reduced net primary productivity and altered disturbance patterns can be expected in dry, east-side forest ecosystems in Montana and Washington under climatic warming. In addition, empirical studies show that climatic variability has strong teleconnections with tree growth and regeneration at annual to decadal scales, resulting in predictable, directional changes under different climatic scenarios. A transect of mountain bioregions from the Pacific Coast to the Rocky Mountains, which builds on past research, is determining how future climatic variability will affect wilderness in the context of regional ecosystem dynamics.

Mountains are a dominant feature of our planet, covering one-fifth of the terrestrial biosphere and being home to one-tenth of the earth's human inhabitants (Messerli and Ives 1997). Because of their steep environmental gradients and complex topography, mountains also have higher rates of endemism, greater ecological heterogeneity and more biodiversity than many lowland environments (Beniston and Fox 1996; Denniston 1995). Equally important, mountains are the 'water towers' of the world, providing 50% of the freshwater that humans consume (Liniger and others 1998). Mountains contain sacred sites for most of the world's major religions and are now part of robust tourism and recreation economies. Because mountains were typically last to be developed and are still relatively underdeveloped, they often are refugia for organisms extirpated elsewhere (such as grizzly bear [*Ursus arctos*]) and are disproportionately well-represented in the world's protected areas, such as national parks and designated wildernesses. Such wilderness areas also are the only places where we can learn how relatively unaltered natural systems work, and they serve as benchmarks against which the state of human-dominated systems can be compared. Thus, mountain wildernesses are globally important and affect people even great distances from mountains.

Mountain wildernesses worldwide are being affected by global-scale environmental stressors, such as increasing atmospheric pollution and climatic change. They also are being impacted by nearby landscape fragmentation, introductions of diseases, exotic plant invasions, increasing recreational pressures and, over the past century, alteration of natural fire regimes.

The potential for ecological change in mountainous national parks of the western United States was recognized and addressed by the National Park Service (NPS) when it initiated research programs in 1990 under the U.S. Global Change Research Program. The NPS program objectives were to (1) contribute to our understanding of ecosystem response to climatic change, (2) detect and document changes attributable to climatic change as part of a national monitoring network and (3) assess the future impacts of climatic change on the natural resources the NPS is charged with protecting in the parks.

Two of the national parks included in the NPS global change program were Olympic and Glacier National Parks (fig. 1). The global change program was transferred to the U.S. Geological Survey in 1996 but the overall goals remained the same. In this paper, we summarize some of the

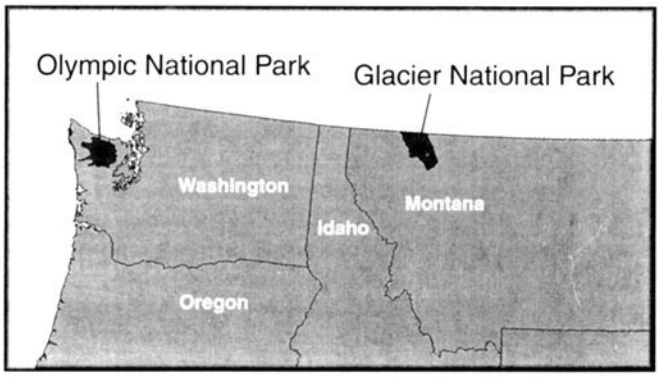

Figure 1—Olympic and Glacier National Parks were two parks studied under the National Park Service's Global Change Research Program.

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responses of Glacier and Olympic National Parks to global-scale environmental change and contrast differences in their responses due to regional sources of disturbance. We describe an approach for integrating the effects of differently scaled ecosystem stressors into assessments of the possible future conditions of mountain wildernesses.

Study Areas

Glacier and Olympic National Parks are both large, wilderness-dominated parks near the United States-Canada border in the northern Rocky Mountains and on the Olympic Peninsula, respectively (fig. 1). Each Park encompasses mountains with similar topographic relief, numerous glaciers and expansive conifer forests; each is snow-dominated, acts as the headwaters for its region and contains relatively intact floral and faunal assemblages. Climate is controlled by dominant air masses, providing Olympic with a maritime climate and Glacier with a more continental climate. Thus, winter temperatures are moderate in the Olympics and cold in the northern Rockies. Summer precipitation as a proportion of annual precipitation is greater in the northern Rockies than in Olympics. Precipitation varies dramatically between westside and eastside locations within each park. For example, precipitation in the Olympic Mountains ranges from >600 cm/yr on Mt. Olympus to only 40 cm/year in the northeastern rainshadow. Precipitation in the northern Rockies varies from 350 cm/yr (westside, high elevation) to 30 cm/yr (eastside, low elevation). This contrast in precipitation over relatively small distances has a profound impact on microclimate, vegetation distribution and disturbance regimes (Peterson and others 1997).

Vegetation is dominated by coniferous forest, with species distribution and abundance varying along elevational gradients (extending to alpine vegetation) and from westside to eastside (including grassland). The western Olympics are dominated at low elevations by temperate rainforests with high biomass and abundant woody debris. Biomass and productivity generally are lower in the northern Rockies. The parks have 10 coniferous species and several plant communities in common, which allows for comparisons of biotic responses to climatic shifts.

Responses to Climatic Change

The environments of both parks have experienced a warming trend since the end of the "Little Ice Age", a ca. 250-year cold period ending around 1850. Historic temperature records since 1880 from locales near current park boundaries show an increase of 1.7° C or more in annual average temperature (Finklin 1984). The natural resources of each Park have responded accordingly.

Glaciers

Glaciers have generally receded for the past 150 years, with several periods of rapid retreat. At Glacier National Park, for instance, only 37 glaciers remain of the 150 estimated to have existed around 1850 (Carrara 1989). Furthermore, the remaining glaciers have been reduced to one-third their previous areas or less (Key and others in press). The total ice and permanent snow coverage of the Park has been reduced 72%, and numerous valleys no longer have any glaciers in their upper reaches. The period of accelerated glacial retreat early this century was correlated with an upward shift in summer temperatures (fig. 2) and, despite considerable variability in summer temperatures and slight increases in precipitation, glaciers continued to shrink. Continued warming is forecast to eliminate all glaciers at Glacier National Park by 2030 (Hall 1994). Similar glacier retreats have been recorded for the Blue Glacier and others in the Olympic Mountains, although the loss of entire glaciers is not as prevalent due to a higher-snowfall climate.

Glaciers are excellent barometers of climatic change because, unlike biological organisms, they do not adapt to change but merely reflect them. Glaciers also tend to reflect decadal or longer climatic trends rather than year-to-year variation. Thus, the documented glacial recessions in these parks are indicators of directional climate change and suggest that other ecosystem changes are likely taking place. The loss of glaciers in mountain watersheds may have significant ecological effects because glacial meltwater can be important in providing minimum baseflow and cool water temperatures for streams during late summer. This, in turn, has implications for temperature-sensitive stream macroinvertebrates and the biota dependent on them.

High-Elevation Forest Responses

Many mountain environments have experienced greater increases in average temperature than have lowland areas (Oerlemans 1994). High-elevation tree species have responded where temperature and permanent snow coverage previously limited tree establishment and growth. In Pacific Northwest mountains, subalpine fir (*Abies lasiocarpa*) have been displacing subalpine meadows, particularly since the 1930s (Rochefort and Peterson 1996). This rapid regeneration of subalpine fir is most pronounced on the (wet) west side of the mountains during periods of warmer, drier climate and on the (dry) east side of the mountains during periods of cooler, wetter climate. Precipitation is more critical than temperature where duration of snowpack limits length of the growing season (west side) and summer soil moisture limits seedling survival (east side). Analysis of repeat photographs in Glacier National Park has documented similar invasions of meadows by subalpine fir. If climate becomes warmer and drier during the next century, continued regeneration of trees may displace much of the remaining meadows within wetter regions of the subalpine forest-meadow mosaic of both Parks.

More vigorous establishment and growth of high-elevation forests is also evident at treeline. At Logan Pass in Glacier National Park, krummholz patches have expanded to fill inter-patch spaces, and there has been a demonstrable trend of krummholz shifting to upright tree forms (Klasner 1998). Although treelines have not moved upslope, the treeline ecotone has become more abrupt as the density of krummholz increased (Butler and others 1994).

In addition to increased establishment of trees and expansion of krummholz at treeline, high-elevation forests at several locations in western North America have experienced increased growth rates, presumably related to increased temperature, increased atmospheric CO_2, less

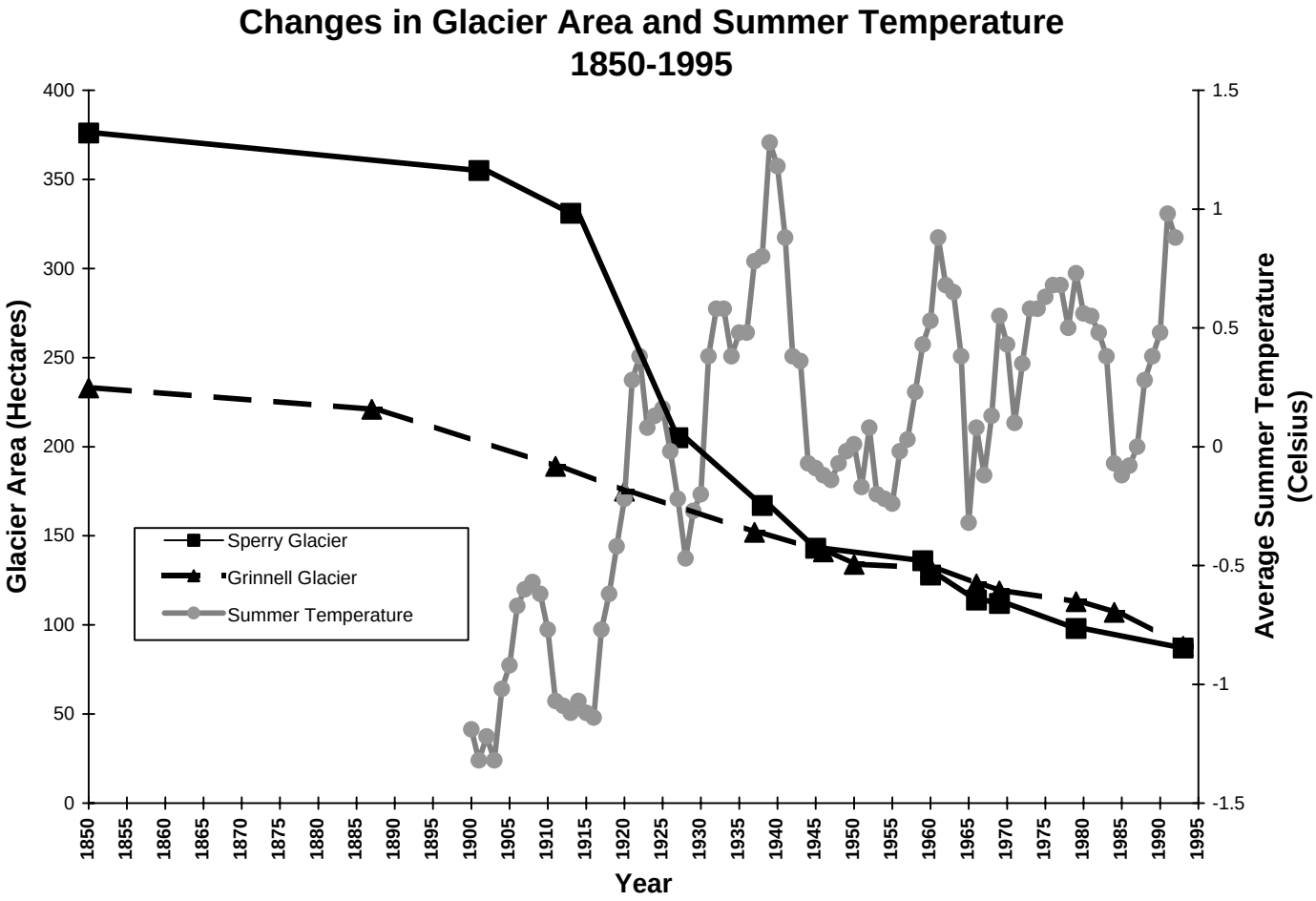

Figure 2—An upward shift in summer temperatures in Glacier National Park accelerated the melting of two park glaciers, Sperry and Grinnell. Glaciers respond slowly to temperature shifts and incorporate numerous year-to-year climatic variations into an integrated response.

extreme or variable conditions and other atmospheric factors (Peterson 1998). The response of tree growth to climatic variability is spatially and temporally variable with aspect, elevation, landform, soil and other site characteristics being important (Ettl and Peterson 1995). However, duration of snowpack dominates growth response to climate by affecting the length of growing season. Thus, predictions that snowpack will be two months shorter in duration at Glacier National Park (Running and Nemani 1991) or that snowlines may rise in Pacific Northwest mountains (Lettenmaier 1992) have profound implications for forest growth response in these wilderness areas.

Responses to Other Stressors

Although both parks have been subjected to similar global-scale environmental change, there are differences in the other stressors to which they are exposed. These will shape ecosystem responses to climatic change in ways still unquantified.

The Olympic Mountains owe much of their unique species assemblage to their partial isolation on a peninsula, surrounded on three sides by seawater and to the south by a major river. This geographic situation altered the impacts of past glaciations on this biota (Peterson 1998), accentuating the ecological traits of a biogeographic isolate. In addition, Olympic National Park is now a more distinct ecological island due to extensive landscape alteration on the peninsula. An abrupt change in vegetation that mirrors the border between national park lands and state and private land is due to extensive logging and other human activities. This loss of connectivity to an intact regional landscape inhibits the dynamic flow of species, energy and other resources necessary to maintain biodiversity and other ecosystem attributes. The increased boundary with altered landscapes increases rates of exotic plant establishment and the potential for introduced diseases. Indeed, Olympic National Park has 166 exotic plant species. In contrast, Glacier National Park is surrounded by mostly intact landscapes, with its sister park in Canada, Waterton Lakes National Park, to the north and the Bob Marshall Wilderness Complex to the south, providing regional connectivity along the Continental Divide. Such landscape connectivity allowed natural recolonization by gray wolves (*Canis lupus*) into Glacier National Park and allows Glacier to act as a source for grizzly bear dispersal.

Another important contrast is in the proximity to urban areas. Olympic National Park borders Puget Sound, where

major cities and millions of people are located. One measure of this potential impact is in the levels of tropospheric ozone in Puget Sound, which have exceeded U.S. national ambient air quality standards on numerous occasions and have reached 150 ppbv (a measure of average ozone concentration) (Brace and Peterson 1998, Cooper and Peterson 1999). Ozone concentrations frequently exceed 80 ppbv during the summer months, a level considered potentially injurious to sensitive vascular plant species (Reich and Amundson 1985). In contrast, Glacier National Park is located far from major cities and has near-background levels of ozone for most of the year and peak ozone concentrations of 60 ppbv.

Although Glacier potentially is subjected to fewer sources of disturbance than Olympic, it functionally has lost a keystone species, the whitebark pine (*Pinus albicaulus*), to an introduced pathogen (Kendall 1995). White pine blister rust (*Cronartium ribicola*) was introduced in the early 20th century on plant stock from Europe and has been progressively killing whitebark pine throughout its range. Glacier has lost 90% of this high-elevation tree species to blister rust, leaving tree "skeletons" in its wake. Whitebark pine nuts provided a critical food source for Clark's nutcracker (*Nucifraga columbiana*), grizzly bear, and Native Americans prior to its loss from the subalpine areas of the Park. Whitebark pine appears to facilitate subalpine fir establishment near treeline, and may play an important role in snow retention in subalpine forests. In contrast, Olympic National Park has few whitebark pine, infection rates have been lower, and, consequently, this keystone species has not been lost.

In addition to climatic change and regional external impacts described above, both parks have undergone change within their boundaries from other disturbance sources. There has been heavy historic use of the parks from eras when large lodges and roads were built and the backcountry saw large groups of horses used to transport visitors to the alpine areas of the mountains. Later infrastructure development included campgrounds, visitor centers and restaurants. Perhaps the greatest human impact on park ecosystems stems from the exclusion of lightning-caused fires, which has led to increased fuel loads, promoted insect outbreaks and altered nutrient cycling in some forests with high-frequency fire regimes. Trying to account for the effects of park use and management in the context of a changing climate and regional landscape disturbance presents an almost unmanageable list of factors that can drive ecosystem change. Achieving a coherent understanding on which to base decisions presents scientists and managers alike with a formidable challenge and necessitates new approaches and new tools to address such complicated issues and their interactions.

Implementing an Integrated Approach

Ecosystem modeling provides a partial solution to such problems because computers can store and organize large amounts of existing information and simulate quantified ecosystem responses for measuring management outcomes or different levels of disturbance. This "cyber-symbiosis" between ecologists, who provide the established ecological relationships reduced to computer code, and computers, with vast memory and ability to process multiple relationships simultaneously, gives us unprecedented opportunities for understanding wilderness ecosystems and making natural resource decisions with a better foundation.

In order to better understand the impacts of climatic change and regional landscape disturbance on mountain wilderness integrity in Olympic and Glacier National Parks, we developed integrated programs of ecosystem modeling and extensive field studies with numerous university and federal agency collaborators whose work is cited below. Our goals were to (1) quantitatively estimate the major ecological processes of these areas, (2) compare simulated and observed wilderness responses to current climate and (3) use these capabilities to estimate responses to future stressors, such as increased climatic variability or changes in frequency and intensity of forest fires. This approach was initially developed and applied to Glacier National Park wilderness and is summarized below.

We further developed and used the Regional Hydro-Ecological Simulation System (RHESSys) to estimate ecosystem processes and changes in mountain environments (Band and others 1991, 1993). RHESSys combines remote sensing, ecological modeling and geographic information system technologies to produce and map spatially explicit estimates of various processes such as evapotranspiration and hydrologic outflows (fig. 3). Satellite-based sensors, such as those on the Landsat Thematic Mapper, provide estimates of leaf area index, a measure of plant photosynthetic capability for each spatial unit throughout the mountain topography. Using a daily mountain climate estimator, such as MTCLIM (Hungerford and others 1989) or DAYMET (Thornton and others 1997), and algorithms describing tree physiology (Running and Gower 1991), RHESSys estimates net primary productivity and other dynamic ecosystem properties for combinations of slope, aspect, and elevation. Given daily climatic data for a particular period, RHESSys also calculates daily water balance for a drainage and provides stream discharge. A topographically sensitive routing routine was incorporated to better distribute water dynamically through mountain watersheds (White and Running 1994). This improved estimates of stream discharge and provided insights into the sensitivity of the model to scaling issues.

Another model, FIRE-BGC, combines a gap-phase succession model and a forest biogeochemistry model to estimate stand-level dynamics, accumulated carbon and tree regeneration, growth, and mortality (Keane and others 1996). This allows FIRE-BGC to estimate large woody debris, duff depth and other characteristics important for assessing forest fire frequency and, with FARSITE (Finney 1998), to map the perimeter and intensity of those fires. By explicitly modeling the successional response of the landscape to simulated forest fires, FIRE-BGC forecast future landscape mosaics and their influence on future ecosystem processes (Keane and others 1999). Overall, RHESSys and FIRE-BGC reasonably predicted the structure and composition of mountain forest communities and the daily rates of ecosystem processes at various spatial scales (White and others 1998).

However, model performance needed to be determined by comparing simulated ecosystem processes with the real thing—measurements of key outputs. Our model validation used seven years of field data on mountain climatology,

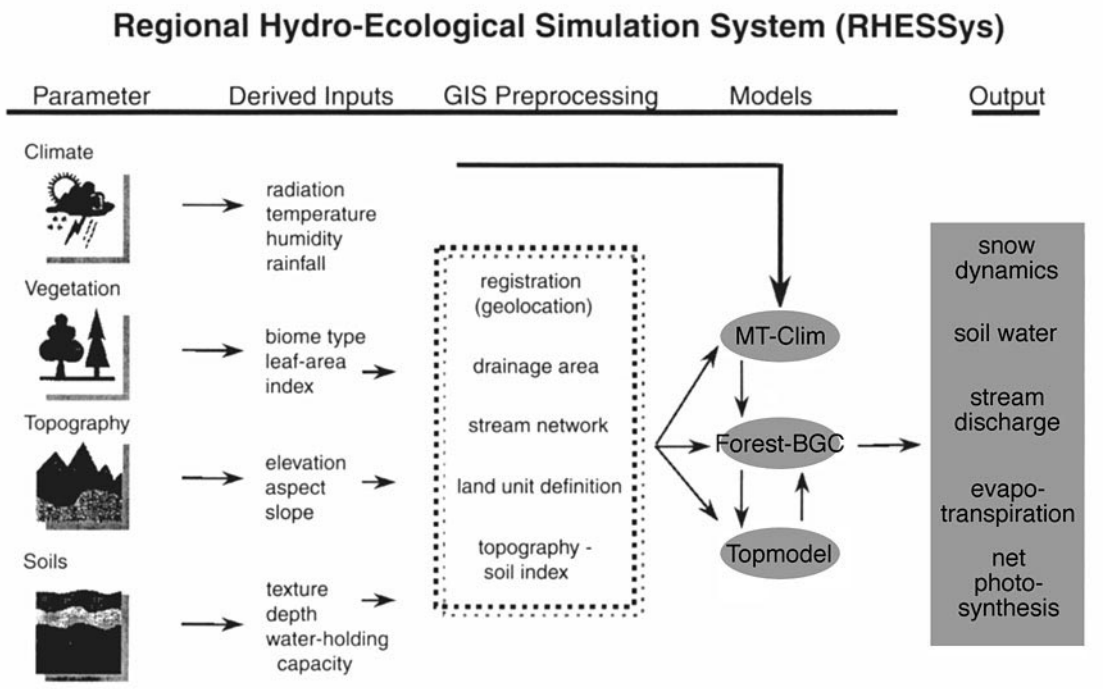

Figure 3—A depiction of inputs, outputs, and modeling steps used in one of the simulation systems for estimating ecosystem processes at Glacier National Park.

snow distribution, glacier activity, stream hydrology, aquatic biota, forest demographics and soil respiration. For instance, over 4,500 snow measurements, taken from a variety of slopes and aspects in two topographically diverse mountain watersheds (approximately 400 km^2 each), correlated well with model estimates (Fagre and others 1997). Similarly, hydrographs (daily discharges measured for a year) from seven streams continuously monitored for seven years compared well with those simulated by the models for that period using climatic data (fig. 4). In watersheds with remnant glaciers, however, higher observed values during late summer underscored both the contributions of glacial meltwater to streamflow and the need to include this source in future models of mountain hydrology.

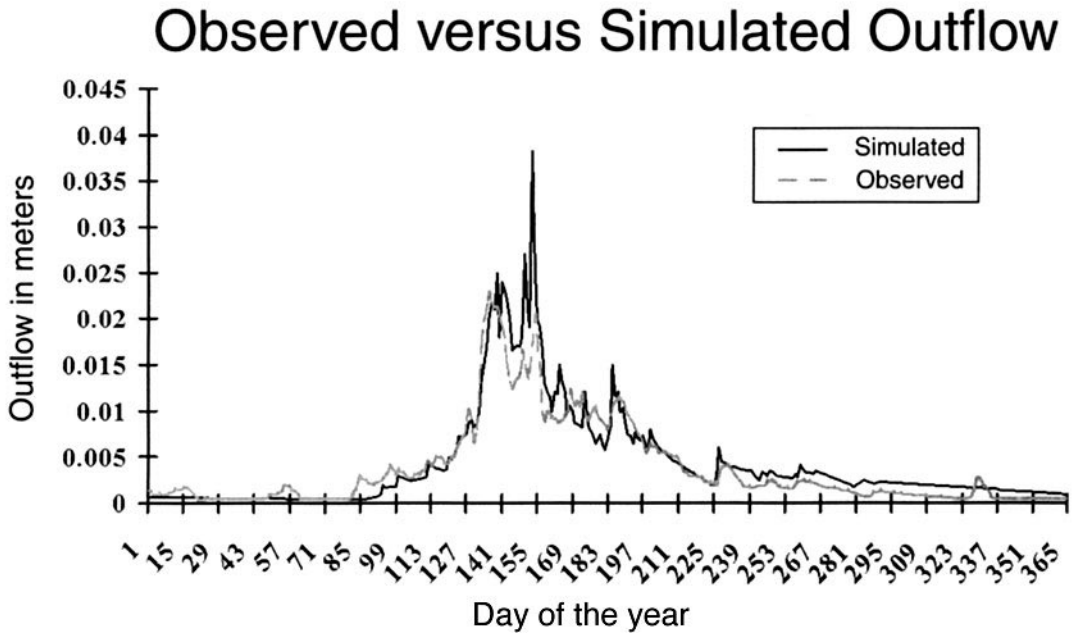

Figure 4—Comparison of observed daily stream outflow and computer-simulated outflow for McDonald Creek in Glacier National Park.

Modeled stream temperatures closely reflected observed values from electronic dataloggers placed in the streams at various elevations (Fagre and others 1997). Frequent monitoring of stream macroinvertebrates clearly showed that predictable species replacement along different sections of the streams was tied to water temperature rather than other variables such as substrate particle size (Hauer and others 1999). This suggests that general warming of stream water temperatures due to earlier snowmelt and loss of glaciers will cause an upslope migration of those macroinvertebrates with narrow thermal tolerances.

Numerous forest plots throughout both study watersheds were selected to represent various combinations of slope, aspect and elevation. Measurements of stand characteristics, such as stem density, were made at each plot and compared to FIREBGC estimates for the same area. Most forest attributes were accurately estimated, but net primary productivity and evapotranspiration in early seral forest stand were underpredicted, because undergrowth ecosystem processes are not simulated at the detail provided for tree species (Keane and others 1996).

One of the major strengths of an ecosystem model, if successfully validated for a specific mountain wilderness, is the ability to envision future conditions by applying different climatic and management scenarios. For instance, with a 30% increase in precipitation and 0.5° C increase in annual temperature for the next 200 years, many mesic tree species, such as western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*), are predicted to expand in the valley bottoms on the west side (White and others 1998). However, fuel loads and potential fire intensity, size and frequency also may increase, especially if fire suppression policies keep interim fire frequency low (Keane and others 1999). Net primary productivity and available nitrogen increase when fire exclusion is reduced. Subalpine tree communities, however, become increasingly nitrogen-stressed, especially when interannual variability is increased in the modeled future scenarios (White and others 1998). Upper and lower treelines shift upward, and increased smoke emissions (and lower air quality) may become future problems if prescribed natural fire management is used to counteract increased fuel loads (Keane and others 1997).

In addition to evaluating the impacts of management and future climate on wilderness resources, ecosystem modeling can be used to improve current management programs. For instance, monitoring will be more efficient if focused on resources or areas that models suggest are most vulnerable to change (fig. 5). Using the same climatic scenario described above, we found that one sub-drainage of the McDonald watershed would have water temperature increases four to five times greater than others. This area would be a candidate for detecting early and pronounced change and would indicate more pervasive changes to come. We also examined a climatic change scenario in which average temperatures did not increase, but the variability did. The eastern side of Glacier National Park responded more dramatically than did the western side of the Continental Divide. Significant reductions in net primary productivity occurred on the eastern side as trees underwent stress during more frequent droughts (White and others 1998). Some scenarios indicate an eventual conversion to grasslands. Thus, the eastern vegetation represents a more vulnerable resource and may warrant additional monitoring and management attention.

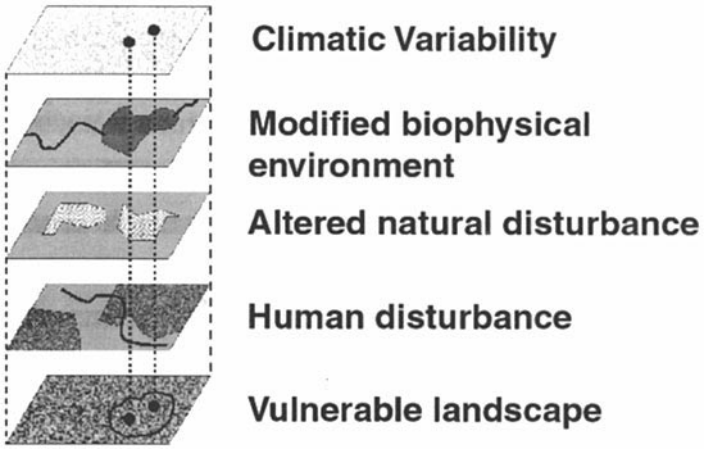

Figure 5—Ecosystem models can identify potentially more vulnerable landscapes within mountainous regions by accounting for multiple sources of disturbance and variability. These vulnerable landscapes can be the focus of monitoring programs for early detection of regional change.

The Future

The approach described above has provided new insights into the present dynamics and possible future conditions of a mountain wilderness at Glacier National Park. However, the influence of surrounding land use/land cover change was explicitly not considered. The modeling tools developed to date urgently need to be refined and strengthened by application to Olympic National Park, where a history of mountain ecosystem studies can provide ample data for model parameterization and validation.

To address the issue of the regional context in which these mountain wildernesses function, we extended existing efforts and initiated a long-term research program on three bioregions that represent a gradient of disturbance intensity and climatic variability (fig. 6). All three bioregions are near the same latitude (47 to 49°N), have contrasting westside vs. eastside precipitation and similar topographic relief, and share numerous other characteristics; they vary primarily by overall climatic regime and degrees of landscape alteration. The Olympic bioregion, with Olympic National Park at its core, is a maritime-influenced climate and has the greatest degree of landscape fragmentation and external stressors. The north Cascades bioregion, with North Cascade National Park at its core, represents an intermediate climatic regime and disturbance level. The northern Rockies bioregion, with Glacier National Park at its core, has the driest, most continental climate and the least disturbed regional context.

Building on existing capabilities and data, we will quantitatively assess the relative roles of climatic change and landscape alteration in determining the future integrity of these mountain wilderness areas. The ecosystem modeling is scale-sensitive so that we can examine the

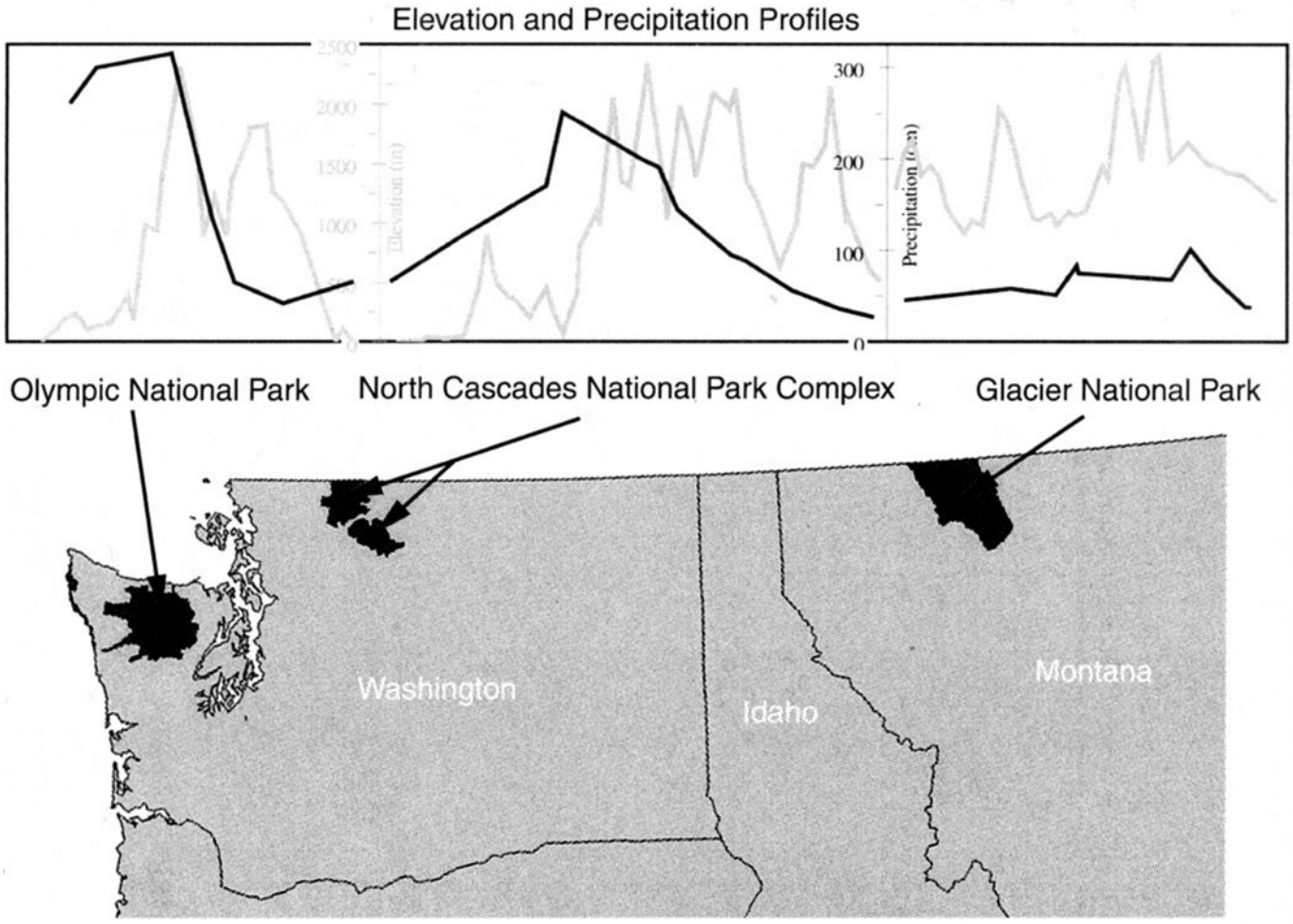

Figure 6—Three National Parks, at the core of larger bioregions surrounding them, represent a gradient of climate regimes, landscape fragmentation and disturbance along a transect from the West Coast to the edge of the Great Plains.

dynamics of change for resources at different spatial scales. For instance, the invasion of meadows by subalpine fir may be ecologically significant at the species scale but will not contribute much to regional-scale estimates of net primary productivity.

Ultimately, we can quantitatively assess the contribution of mountain wilderness areas to the ecological dynamics of the bioregions to underscore their value to our daily lives. Coupled with the ability to make forecasts using different climate and management scenarios, this enhanced perspective on the ecological services that wilderness can provide should lead to better management decisions and stronger public support for wilderness.

Acknowledgments

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References

Band, L. E.; Patterson, P.; Nemani, R. R.; Running, S. W. 1993. Forest ecosystem processes at the watershed scale: incorporating hillslope hydrology. Agricultural and Forest Meteorology. 63:93-126.

Band, L. E.; Peterson, D. L.; Running, S. W.; Coughlan, J.; Lammers, R; Dungan, J.; Nemani, R. 1991. Forest ecosystem processes at the watershed scale: basis for distributed simulation. Ecological Modelling. 56:171-196.

Beniston, M.; Fox, D. G. 1996. Impacts of climate change on mountain regions. In: Watson, R. T.; Zinyowera, M.; Moss, R. H.; Dokken, D. J., eds. Climate Change 1995—Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses; Cambridge University Press; Cambridge, UK: 191-213.

Brace, S.; Peterson, D. L. 1998. Spatial patterns of tropospheric ozone in the Mount Rainier region of the Cascade Mountains, U.S.A. Atmospheric Environment. 32:3629-3637.

Butler, D. R.; Malanson, G. P.; Cairns, D. M. 1994. Stability of alpine treeline in northern Montana, USA. Phytocoenologia. 22:485-500.

Carrara, P. E. 1989. Late Quaternary glacial and vegetative history of the Glacier National Park region, Montana. U.S. Geological Survey Bulletin 1902. 64 p.

Cooper, S. M. and D. L. Peterson. 1999 (In Press). Tropospheric ozone distribution in western Washington. Environmental Pollution.

Denniston, D. 1995. High Priorities: Conserving Mountain Ecosystems and Cultures. Worldwatch Paper 123; Worldwatch Institute, Washington, D. C.: 80 p.

Ettl, G. J. and D. L. Peterson. 1995. Growth response of subalpine fir (*Abies lasiocarpa*) to climate in the Olympic Mountains, Washington, USA. Global Change Biology. 1: 213-230.

Fagre, D. B; Comanor, P. L.; White, J. D; Hauer, F. R.; Running, S. W. 1997. Watershed responses to climate change at Glacier National Park. Journal of the American Water Resources Association. 33:755-765.

Finklin, A. I. 1986. A Climatic Handbook for Glacier National Park—with Data for Waterton Lakes National Park. General Technical Report INT-204; USDA Forest Service Intermountain Research Station, Ogden, UT.

Finney, M. 1998. FARSITE: Fire Area Simulator—model development and application. USDA. Forest Service Research Paper RMRS-RP-4; Rocky Mountain Research Station, Ogden, UT.

Hall, M. H. P. 1994. Predicting the impact of climate change on glaciers and vegetation distribution in Glacier National Park to the year 2100. M.S. Thesis, State University of New York, Syracuse.

Hauer, F. R.; Stanford, J. A.; Giersch, J. J.; Lowe, W. H. 1999 (In Press). Distribution and abundance patterns of macroinvertebrates in a mountain stream: an analysis along multiple environmental gradients. Verh. Internat. Verein. Limnol.

Hungerford, R. D.; Nemani, R. R.; Running, S. W.; Coughlan, J. C. 1989. MT-CLIM: a mountain microclimate simulation model. USDA Forest Service Research Paper INT-414; Intermountain Research Station, Ogden, UT.

Keane, R. E.; Morgan, P.; White, J. D. 1999. Temporal pattern of vegetation communities and ecosystem processes on simulated landscapes of Glacier National Park, USA. Landscape Ecology. 14:311-329 .

Keane, R. E.; Hardy, C. C.; Ryan, K. C.; Finney, M. A. 1997. Simulating effects of fire on gaseous emissions and atmospheric carbon fluxes from coniferous forest landscapes. World Resource Review. 9:177-205.

Keane, R. E.; Ryan, K. C.; Running, S. W. 1996. Simulating effects of fire on northern Rocky Mountain landscapes with the ecological process model FIRE-BGC. Tree Physiology. 16:319-331.

Kendall, K. C. 1995. Whitebark pine: ecosystem in peril. In: LaRoe, E. T., ed. Our Living Resources, U.S. Dept. of Interior, National Biological Service, Washington, D.C.: 228-230.

Key, C. H.; Fagre, D. B.; Menicke, R. K. In Press. Glacier recession in Glacier National Park, Montana. In: Williams, R. S.; Ferrigno, J., eds. Satellite Image Atlas of Glaciers of the World. Vol. U.S. Geological Survey Professional Paper 1386-J. United States Government Printing Office. Washington D.C.

Klasner, F. L. 1998. Spatial changes in alpine treeline vegetation patterns along hiking trails in Glacier National Park, Montana. M.S. thesis, Oregon State University, Corvallis.

Lettenmaier, D. P. 1992. Sensitivity of Pacific Northwest water resources to global warming. Northwest Environmental Journal 8:265-274.

Liniger, H.; Weingartner, R.; Grosjean, M. 1998. Mountains of the World: Water Towers for the 21st Century. University of Bern, Switzerland.

Messerli, B.; Ives, J. D. eds. 1997. Mountains of the World: A Global Priority. Parthenon Publishing, New York.

Oerlemans, J. 1994. Quantifying global warming from the retreat of glaciers. Science. 264:243-245.

Peterson, D. L. 1998. Climate, limiting factors and environmental change in high-altitude forests of Western North America. In: Beniston, M.; Innes, J. L., eds. The Impacts of Climate Variability on Forests. Springer, New York: 191-208.

Peterson, D. L.; Schreiner, E. G.; Buckingham, N. M. 1997. Gradients, vegetation and climate: spatial and temporal dynamics in the Olympic Mountains, U.S.A. Global Ecology and Biogeography Letters. 6:7-17.

Reich, P. B.; Amundson, R. G. 1985. Ambient levels of ozone reduce net photosynthesis in tree and crop species. Science. 230:566-570.

Rochefort, R. M.; Peterson, D. L. 1996. Temporal and spatial distribution of trees in subalpine meadows of Mount Rainier National Park, Washington, U.S.A. Journal of Arctic and Alpine Research. 28:52-59.

Running, S. W.; Gower, S. T. 1991. FOREST-BGC, a general model of forest ecosystem processes for regional applications. II. Dynamic carbon allocation and nitrogen budgets. Tree Physiology. 9:147-160.

Running, S. W.; Nemani, R. R. 1991. Regional hydrologic an carbon balance responses of forests resulting from potential climate change. Climatic Change. 19:349-368.

Thornton, P. E.; Running, S. W.; White, M. A. 1997. Generating surfaces of daily meteorological variables over large regions of complex terrain. Journal of Hydrology. 190:214-251.

White, J. D.; Running, S. W. 1994. Testing scale dependent assumptions in regional ecosystem simulations. Journal of Vegetation Science. 5: 687-702.

White, J. D.; Running, S. W.; Thornton, P. E.; Keane, R. E.; Ryan, K. C.; Fagre, D. B.; Key, C. H. 1998. Assessing regional ecosystem simulations of carbon and water budgets for climate change research at Glacier National Park, USA. Ecological Applications. 8:805-823.

Establishing Benchmark Monitoring Points in Wilderness: Successes and Challenges

Charles G. Johnson, Jr.

Abstract—The Western United States has a rich heritage of biological diversity within the wilderness areas. To access human disturbances compared to human-undisturbed sites, the tool of "benchmarking" is used, where sites are compared over time. The resulting data and photographic records are the basis of monitoring used by land managers. Examples are given for three locations, as well as details of monitoring techniques.

Those portions of the landscape that have a long history of protection from human-induced changes, where natural processes are permitted to dominate, are invaluable as places where benchmarking camera points and/or permanent plots can provide investigators with extremely valuable information. Designated wilderness areas often contain extensive landscape segments where human activities have been minimal.

Permanent monitoring points are a collection of site-specific places where steel or aluminum stakes have been left behind to reference the exact point where photography has been taken and where data have been gathered and recorded. They often document the condition of the vegetation at a given point in time. When disturbances occur, either natural or human-induced, these sites provide golden opportunities to rephoto and resample to document the changes resulting from the disturbance. As used in this writing, monitoring is defined as a field-oriented data collection and photographic documentation event conducted at established camera point, plot center or transect-defining stakes.

A History of Monitoring—Examples from the Wallowas, Seven Devils, and Hells Canyon

The earliest use of staked points for photography and data gathering occurred from 1907-1911 in subalpine green fescue grasslands in the Wallowa Mountains. Arthur W. Sampson, a research scientist from the Bureau of Plant Industry, was sent from Washington, D.C. to determine how to advise managers on stopping the deterioration of rangelands and improve the range condition. His five-year study provided several landmark publications, which provided the basis for revegetation practices and changes in management practices on Western rangelands. He is known today as the "father of American range management." The sites he monitored have been periodically rephotographed and re-evaluated using his staked locations.

Elbert H. Reid was a range ecologist for the Pacific Northwest Forest and Range Experiment Station in 1938 when he first visited Tenderfoot Basin of the Wallowa Mountains. He came to study the green fescue rangelands, which were in various stages of depletion from overgrazing by domestic sheep. As a result of his collaboration with G.D. Pickford, the study sites provided information and findings for their landmark publication in 1942 - "Basis for Judging Subalpine Grassland Ranges of Oregon and Washington." He returned in 1956 to establish the sites for future use by marking the locations on the ground. Then, beginning in 1968, and continuing each decade since, Reid and his followers have returned to document the changes in plant community composition and successional relationships at each of the permanently marked sites.

In 1953, the first Parker 3-Step Condition and Trend transects were installed as part of a national rangeland monitoring system in the rangelands of the Wallowa-Whitman National Forest. The decade between 1955 and 1965 provided the Wallowa Mountains and the associated canyonlands of the Snake and Imnaha Rivers with the baseline network of "C&T" transect clusters which now offer almost 40 years of photographic and sampled data showing the changes resulting from grazing, fire and climate.

In 1977, the first ecological baseline plots were installed in the canyonlands and mountainous terrain of the Snake River and Wallowa Mountains. By 1987, the plots established to characterize the plant associations of the Wallowa - Snake Province numbered over 1,500. Of this plot population, more than 1,000 plots were established in the dedicated wildernesses of the Wallowa Mountains (Eagle Cap Wilderness Area) and the Seven Devils Mountains and Snake River Canyon (Hells Canyon Wilderness). These sites were permanently staked, photographed, sampled and referenced for future use to demonstrate changes caused by natural or management-induced events. Although access to these remote areas is difficult, the value of the permanent monitoring points as benchmarks in less-disturbed lands makes the effort of installation worthwhile.

In 1979, David Cole, a research scientist with the Intermountain Research Station in Missoula, Montana, installed permanent monitoring stakes on 26 sites in the Lake Basin of the Eagle Cap Wilderness. These sites were selected to benchmark successional stages resulting from severity of use by humans and their livestock at campsite locations. David has returned twice (1984 and 1990) to rephoto and resample the vegetation for species composition, areal colonization and trend assessment.

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Marking significant disturbance events is one of the key values of having permanent monitoring points established and sampled prior to the unknown disturbances that befall these sites. Examples of naturally occurring disturbances in wildernesses are wildfires, grazing use by native ungulates, mass wasting events such as landslides, slumps or debris flows, and climatic changes. Examples of human-induced or nonnatural disturbances in wildernesses are domestic grazing and recreational impacts. Also of concern to the wilderness manager are lack of periodic natural disturbance events important to the ecosystems (retardation of natural fire return) and by numbers of species out-of-balance with historic levels (elk and deer populations; alien plant infestations).

An example from the Hells Canyon Wilderness that demonstrates the value of permanent monitoring points occurred when the Salt Creek Burn visited 52,600 acres in 1996. The permanent monitoring points established prior to that fire were Parker Condition and Trend (C&T) transects, ecological classification plots and one three-way exclosure. Of the 76 monitoring points established within the burn area, 40 of the sites were burned and available for study of fire succession across a variety of different plant communities affecting a broad array of plant associations.

Techniques Employed for Monitoring

The basic concept was to locate a plant community that represents a particular seral stage of a given plant association, drive a stake into the ground at the stand center, take pictures of the desired views from that stake and collect baseline environmental and plant data. It was deemed important to reference the site for future relocation and anticipate that the next investigator would be someone unfamiliar with the previous work. Therefore, aerial photos were pin-pricked and labelled; USGS quadrangle maps were labelled; and a permanent monitoring point reference sign was placed onsite. The completed work on one permanent monitoring point did not end here. After field work was completed, the office portion of the monitoring task was begun. This involved labeling the photography, setting up a hard-copy file for the data cards, maps and photography and inputting the data into an electronic data base. In addition, the mapped locations were digitized into an electronic GIS data layer. Finally, a retake/resample "promise" system was devised to assure that the sites were revisited at a designated date in the future.

Plots were sampled using two different techniques. For reconnaissance-level plots, the size was 375 square-meters (roughly one-tenth acre) in a circle, with the camera point at the center where a steel stake was driven. For photographic documentation, the investigator chose an unspecified number of views radiating from the plot center outward to the skyline (long oblique photos) and/or to the foreground (short oblique photos). For more intensively sampled sites, transects were employed, with small microplots sampled along the transect lines. Usually two 100-foot transects were placed within the general area of the reconnaissance plot. Then up to 40 microplots were sampled using one-square foot quadrats placed systematically along the two transects. In addition one-square yard quadrats were photographed at systematic locations straddling the transect lines to accompany the general views taken from the ends of the transects of the overall site.

Conclusion

Designated wilderness areas provide a rich mix of forestland, shrubland, grassland and wetland ecosystems. In the western United States, topographic relief generally is a feature of either canyonland or mountainous landforms included in most designated wildernesses. This relief enhances landscape diversity and, with the varying aspects, promotes a high biological diversity for the areas. With such a rich heritage of biological diversity included within our wilderness areas, it is critical that we document the baseline ecological condition (seral stages) of the plant populations and plant communities. From this baseline of "benchmark" plots and camera points, land managers can utilize the photographic and sampled data to enhance the management of our wilderness areas.

References

Cole, David N. 1982. Wilderness campsite impacts: effect of amount of use. Res. Paper INT-302. Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 42 p.

Cole, David N. 1986. Ecological changes on campsites in the Eagle Cap Wilderness, 1979 to 1984. Res. Paper INT-368. Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 15 p.

Cole, David N.; Hall, Troy E. 1992. Trends in campsite condition:Eagle Cap Wilderness, Bob Marshall Wilderness, and Grand Canyon National Park. Res. Paper INT- 453. Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 40 p.

Cole, David N. 1993. Campsites in three western wildernesses:proliferation and changes in condition over 12 to 16 years. Res. Paper INT-463. Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 15 p.

Johnson, C. G. Jr.; Simon, S. A. 1987. Plant Associations of the Wallowa-Snake Province. R6-ECOL-TP-225A-86. Portland, Oregon. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 399 p.

Pickford, G. D.; Reid, E. H. 1942. Basis for judging subalpine grassland ranges of Oregon and Washington. U.S. Dept. of Agric. Circular 655. 38 p.

Reid, E. H.; Strickler, G. S.; Hall, W. B. 1980. Green fescue grassland: 40 years of secondary succession. Res. Paper PNW-274. Portland, Oregon: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 39 p.

Reid, E. H.; Johnson, Jr., C. G.; Hall, W. B. 1991. Green fescue grassland: 50 years of secondary succession under sheep grazing. R6-F16-SO-0591. Portland, Oregon: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 37 p.

Sampson, A. W. 1908. The revegetation of overgrazed areas. Preliminary report. Forest Service Circular 158. U.S. Department of Agriculture, Washington, D.C. 21 p.

Sampson, A. W. 1909. Natural revegetation of depleted mountain grazing lands. Forest Service Circular 169. U.S. Department of Agriculture, Washington, D.C. 28 p.

Sampson, A. W. 1914. Natural vegetation of rangelands based upon growth requirements and life history of the vegetation. Journal of Agriculture Research 3(2);93-147.

Strickler, G. S.; Hall, W. B. 1980. The Standley Allotment: A History of Range Recovery. Res. Paper PNW-278. Portland, Oregon: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 35 p.

The Importance of Wilderness to Whitebark Pine Research and Management

Robert E. Keane

Abstract—Whitebark pine is a keystone species in upper subalpine forests of the northern Rocky Mountains, Cascades, and Sierra Nevada that has been declining because of recent mountain pine beetle and exotic blister rust epidemics, coupled with advancing succession resulting from fire exclusion. Whitebark pine and Wilderness have a mutually beneficial relationship because 1) half of whitebark pine's range is in wilderness, 2) many wildlife species depend on whitebark pine ecosystems, 3) whitebark pine forests have high recreation value, and 4) whitebark pine landscapes contain unique ecological processes. Wilderness has not escaped the ravages of beetle, rust and fire exclusion, so restoration of these ecosystems may be warranted in some areas. The best wilderness restoration tool appears to be prescribed fires, especially management-ignited burns. This paper discusses whitebark pine ecology and the importance of the species to wilderness, and presents restoration treatments and management alternatives for these remote settings.

Whitebark pine (*Pinus albicaulis)* is an important tree species in many upper subalpine forests of the northern Rocky Mountains, Sierra Nevada and Cascades in the United States and Canada (Arno and Hoff 1990). The species produces large seeds that are highly prized by many animal species, and its forests provide critical wildlife habitat and watershed protection (Hutchins and Lanner 1982; Hann 1990). Healthy stands of whitebark pine can produce over 100 kg ha^{-1} of seed in good cone crop years (Forcella and Weaver 1980). One bird, the Clark's Nutcracker (*Nucifraga columbiana*), has evolved a mutualistic relationship with whitebark pine in which it is the sole vector of seed dispersal (Tomback and others 1990). Whitebark pine forests have recently been declining in the northern portions of its range because of recent mountain pine beetle (*Dentroctonous ponderosae*) and blister rust (*Cronartium ribicola*) epidemics, and advancing succession from more than 70 years of fire exclusion (Keane and Arno 1993; Kendall and Arno 1990). Recent research efforts have been investigating techniques to restore ecosystem health and return fire processes and historical stand characteristics to the declining landscapes (Keane and Arno 1996). However, many whitebark pine stands occur in wilderness areas, which may preclude some proactive restoration techniques.

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Many wilderness areas encompass the same high mountain settings where whitebark pine ecosystems are often found (Cole 1990). In fact, many whitebark pine forests (over 45 percent) occur in wilderness areas or national parks. Wilderness areas will play a critical role in the conservation of this vital species. Some have a semblance of an intact fire regime that would provide critical baseline or reference data for whitebark pine stand and landscape dynamics at large spatial and temporal scales. Unfortunately, many wilderness areas are also experiencing severe whitebark pine declines, and restoration projects may be difficult to implement because of inaccessibility, special regulations and adverse sociopolitical attitudes (Czech 1996). This paper summarizes whitebark pine ecology, presents the importance of wilderness areas to whitebark pine ecosystems and vice versa, and discusses possible restoration treatments and management alternatives for these remote settings.

Background

Whitebark Pine Ecology

Whitebark pine is a long-lived, seral tree of moderate shade tolerance (Minore 1979). Although it can live well over 400 years (the oldest individual is more than 1300 years), it is eventually replaced, in the absence of fire, primarily by the shade-tolerant subalpine fir (*Abies lasiocarpa*), spruce (*Picea engelmannii*), and mountain hemlock (*Tsuga mertensiana*) in the mesic parts of its range (Arno and Hoff 1990; Keane, in press). Whitebark pine also competes with lodgepole pine *(Pinus contorta*) during early successional stages in the lower portions of its elevational range (Arno and others 1993; Mattson and Reinhart 1990). It can take anywhere from 50 to 250 years for subalpine fir to replace whitebark pine in the overstory depending on the local environment and previous fire history (Keane, in press).

Whitebark pine comprises about 10-15 percent of the forested landscape in the upper subalpine zone of the northern Rocky Mountains (Arno and Hoff 1990). Although this species has limited use as a commercial timber species because of its diminutive stature, gnarled growth form and remote setting, it produces seeds that are highly prized for food by many species of wildlife, including the threatened grizzly bear (*Ursus arctos horribilis*) (Mattson and others 1991), red squirrel (*Tamiasciurus hudsonicus*) (Ferner 1974), and Clark's nutcracker (*Nucifraga columbiana*) (Tomback 1989). The Clark's nutcracker plays a critical role in the whitebark pine regeneration process because this bird is essentially the only dispersal vector for the heavy, wingless seed (Tomback 1989; Tomback 1998). Whitebark pine also protects snowpack in high-elevation watersheds and delays snowmelt, providing high quality water to valleys below throughout the summer (Arno and Hoff 1990; Hann 1990).

In general, whitebark pine is found in two types of high mountain environments. Most common are upper subalpine sites where whitebark pine is the major seral species and it is successionally replaced by the shade-tolerant fir, spruce or mountain hemlock, depending on geographic region. These sites support upright, closed-canopy forests but occur at the lower transition to timberline, just above or overlapping with the elevational limit of lodgepole pine (Arno and Weaver 1990; Pfister and others 1977). Sites where whitebark pine is the indicated climax species (that is, it is the only tree species able to successfully reproduce and mature) are found at lower timberline on relatively dry, cold slopes, where trees often occur in elfin forests, clusters, groves or tree islands (Arno 1986; Arno and Weaver 1990; Steele and others 1983). Subalpine fir can occur on these sites, but as scattered individuals with truncated growth forms (Arno and Hoff 1990; Arno and Weaver 1990; Cooper and others 1991; Pfister and others 1977). Whitebark pine can also exist as krummholz on alpine sites (Arno and Hoff 1990; Tomback 1989), and as a minor seral in lower subalpine sites (Cooper and others 1991; Pfister and others 1977), but these sites are not discussed here.

Fire Ecology

Three types of fires define fire regimes in whitebark pine forests (Arno and Hoff 1990; Morgan and others 1994). Some high, dry whitebark pine stands experience recurrent nonlethal underburns because of sparse fuel loadings, but these are mostly confined to the southern parts of the species range in the Rocky Mountains, and represent only a small portion of existing whitebark pine forests (less than 10 percent) (Morgan and others 1994). Most of these areas are still disease-free and within the fire rotation because of the inhospitable conditions for the rust infection and the long fire-return intervals.

The more common, mixed-severity fire regime is characterized by fires of different severities in space and time, creating complex patterns of tree survival and mortality on the landscape. Mixed severity fires can occur at 60- to 300-year intervals (Arno and Hoff 1990; Morgan and others 1994). Individual fires can be surface fires with differential mortality (underburns), stand-replacement fires, and most often, fires that contain elements of both (Morgan and others 1994). Sometimes fire burns in sparse ground fuels at low severities, killing the smallest trees and the most fire-susceptible overstory species, often subalpine fir. Severities increase if the fire enters areas with high fuel loads or if the fire gains entrance into tree crowns due to increasing winds, thereby creating patches of high fire-killed mortality (Lasko 1990). Burned patches are often 1 to 30 ha in size, depending on topography and fuels, and these openings provide important caching habitat for the Clark's nutcracker (Norment 1991; Tomback and others 1990).

Many whitebark pine forests in northwestern Montana, northern Idaho and the Cascades originated from large, stand-replacement fires that occurred at long time intervals (greater than 250 years) (Arno 1986; Keane and others 1994; Morgan and others 1994). Stand-replacement fires also occurred within mixed-severity fire regimes, but as infrequent events. These fires are usually wind-driven and often originate in lower, forested stands (Murray and others 1998).

Whitebark pine benefits from wildland fire because it is more capable of surviving and regenerating after fire than its associated shade-tolerant trees (Arno and Hoff 1990). Whitebark pine is able to survive low severity fires better than its competitors because it has thicker bark, thinner crowns and deeper roots. It readily recolonizes large, stand-replacement burns because its seeds are transported great distances by Clark's nutcrackers. Nutcrackers can disperse whitebark pine seeds up to 100 times farther than wind can disperse seeds of subalpine fir and spruce (McCaughey and others 1985; Tomback and others 1990; Tomback and others 1993). Essentially all whitebark pine regeneration comes from unclaimed nutcracker caches, where seeds eventually germinate and grow into seedlings (Keane and others 1990). Nutcrackers prefer open sites with many visual cues for seed caching, much like the burned stands after a mixed or stand-replacement fire (McCaughey and Weaver 1990; Sund and others 1991; Tomback 1989; Tomback and others 1990; Tomback 1998). Nutcrackers will cache seed in beetle- or rusk-killed stands, but whitebark pine germinants usually will not survive in the shaded subalpine fir understory. Burned patches can be any size for nutcracker caching, but Norment (1991) found frequent caching in patches 1 to 30 ha, about the same size as patches created by mixed-severity burns.

Whitebark Pine Decline

Whitebark pine is declining in areas of the northern Rocky Mountains and Cascades because of several native and exotic processes interacting at different spatial and temporal scales (Arno 1986; Ciesla and Furniss 1986; Keane and Arno 1993; Kendall and Arno 1990). The successional replacement of whitebark pine by subalpine fir and spruce is a process that, prior to 1930, was usually interrupted by naturally occurring fires (Arno and Hoff 1990; Morgan and others 1994). However, 60+ years of fire exclusion have allowed fir and spruce to become dominant in many forests historically dominated by whitebark pine (Arno 1986; Keane and others 1994). The cumulative effects of fire exclusion in these long fire-return interval, high-elevation landscapes would probably not be readily apparent as yet if it had not been for a native pine beetle and an exotic disease.

Extensive mountain pine beetle epidemics during the 1930's and 1940's killed many whitebark pine trees in western Montana and central Idaho (Baker and others 1971). Although this epidemic was extensive and deadly, the whitebark pine ecosystem could have easily recovered if fires had been allowed to burn the beetle-killed landscape (Perkins and Swetnam 1996). Meanwhile, white pine blister rust, an exotic disease brought over from Europe around 1910, started killing whitebark pine forests as early as the 1930's in northwestern Montana, northern and central Idaho and the Cascades (Arno and Hoff 1990; Hoff and others 1980; Keane and Arno 1993; Kendall and Arno 1990). Both the rust and beetle kill mature, cone-bearing trees thereby accelerating the successional replacement of whitebark pine to the more shade-tolerant fir and spruce. Thus, the killing of whitebark pine by rust and beetles, coupled with the lack of fire as a recycling agent, has caused a major shift in landscape composition and structure from one of pine to fir and spruce. Blister rust and beetle have accelerated succession

to subalpine fir by killing mature whitebark pine, thereby truncating an important successional community.

Wilderness and Whitebark Pine

Geography

Whitebark pine ecosystems are important to Pacific Northwest wilderness ecology because they comprise a large component of many high-elevation wilderness areas (Cole 1990). Previous methods used to estimate the extent of whitebark pine in wilderness areas were confounded by inadequate data and small-scale range maps of the species (Arno and Hoff 1990). We used several digital spatial products, statistical analysis and GIS (Geographic Information Systems) techniques to compute the potential and existing range of whitebark pine in wilderness and roadless areas based on knowledge of local whitebark pine topographic relationships. First, we digitized the range of whitebark pine into a GIS from maps of Arno and Hoff (1990) and Little (1971) that coarsely describe the entire range of whitebark pine within the United States. We called this map the **Whitebark Pine Range Map** (figure 1a). This map has many limitations because it was broadly drawn from low resolution maps.

We next imported all the Western State Gap data layers of vegetation created from satellite imagery into the whitebark pine GIS to describe the current distribution of existing vegetation in the western United States (Redmond and Prather 1996, for example). These maps were merged then refined to accurately and consistently characterize mid scale vegetation distribution in categories useful to research and management (Keane and others 1996). We then selected only those polygons that were classified to whitebark pine, or a mixed conifer cover type with whitebark pine dominant, to describe the current distribution of whitebark pine cover types. This map is called the **Existing Whitebark Pine Map** (figure 1b).

A third map, called the **Potential Whitebark Pine Map** (figure 1c), depicts all areas having the potential to support whitebark pine and more narrowly defines the range of the species to elevational limits. First, all lands classified as barren, rock or water identified in the GAP maps were removed from the analysis. The elevational limits of whitebark pine were then defined from the following two regression equations:

$$LEL = 2446.0856 - 0.001321(NOC) \quad R^2 = 0.68, df = 35, SE = 150.21$$
$$UEL = 2838.8867 - 0.001057(NOC) \quad R^2 = 0.87, df = 26, SE = 67.60$$

Where LEL is the lower elevational limit (m), UEL is the upper elevational limit (m), and NOC is the Lambert-Azimuthal North Coordinate (km) from the GIS projection.

These equations were constructed from available field data (Keane and others 1994), personal observations of whitebark pine elevational limits across the northern Rockies and Cascades (Arno and Hoff 1990), and an extensive review of the literature (see figure 2) (Arno 1979; Cooper and others 1991; Pfister and others 1977; Steele and others 1983; Weaver and Dale 1974). Both equations were coded into the GIS to produce a layer that defined all lands that could potentially support whitebark pine. This layer was adjusted to exclude those high-elevation areas outside whitebark pine's geographical range using Arno and Hoff's (1990) map. The final map, shown in figure 1c, provides a more accurate, coarse-scale habitat model for whitebark pine than the Whitebark Pine Range Map. This map is somewhat conservative since Arno and others (1993) found that, historically, whitebark pine was a dominant overstory species hundreds of meters below its current documented distribution.

We then performed the GIS analysis by overlaying land ownership, a layer already built by the USDA Forest Service, with existing and potential (that is, range and regression maps) whitebark pine lands to determine the geographical importance of wilderness to whitebark pine ecosystems (table 1). We stratified potential and existing whitebark pine coverage by land ownership within the states that contained whitebark pine and found that over 47 percent of all potential whitebark pine habitat and 49 percent of all existing whitebark pine stands occur within wilderness and national parks (table 1). This analysis also revealed that about 80 percent of all lands supporting or having the potential to support whitebark pine are managed by the Forest Service in states containing whitebark pine. Over 95 percent of whitebark pine habitat occurs on federal lands with the remainder on state and private lands. The three largest wilderness settings in the western United States, the Bob Marshall Wilderness Complex, the Selway-Bitterroot-Frank Church Wilderness Complex and Yellowstone National Park, have 49, 23 and 47 percent of their lands in potential whitebark pine habitat, respectively (Keane and others 1994). Moreover, nearly all whitebark pine lands are on publicly managed lands allowing for a comprehensive restoration policy across all land management agencies. With nearly half of all current and potential whitebark pine lands in wilderness, wilderness management will inevitably play a crucial role in the perpetuation of this threatened ecosystem.

Ecosystem Processes and Values

Wilderness areas are important reserves for whitebark pine because the adverse effects of 60+ years of fire exclusion have not yet been manifest in portions of some wilderness areas for several reasons. First, most wilderness areas contain high mountain ecosystems where fire intervals are longer than those characterizing lower elevation forests such as ponderosa pine. Therefore, many portions of mountainous wilderness may still be within a natural fire rotation if evaluated at the stand-level. However, if the entire wilderness landscape were analyzed, an unusually large proportion would be in late seral stages dominated by shade-tolerant trees compared to historical landscapes, which had high proportions of young seral forests, and there would be a preponderance of multistoried stand structures, symptomatic of fire exclusion impacts (Habeck 1970; Habeck 1985; Rogeau 1996). Second, some fires have been allowed to burn in some of wilderness areas because of active fire management programs. Beginning in 1973, the Selway-Bitterroot Wilderness has had one of the most active wilderness fire programs in the western United States. Comparing this program to historical fire regimes, Brown and others (1994) found that many areas in the Selway-Bitterroot Wilderness Area were within the historical fire return interval, except

Figure 1—Extent of whitebark pine in the United States. Areas in black are where whitebark pine can be found, and areas in grey are Wilderness areas and National Parks. The areas in black were derived from (a) Whitebark Pine Range Map or potential range of whitebark pine from range map in Arno and Hoff (1990), (b) Potential Whitebark Pine Map or the areas that have the potential to support whitebark pine based on regression analysis, and (c) Existing Whitebark Pine Map, or the extent of current whitebark pine coverage from western state GAP maps.

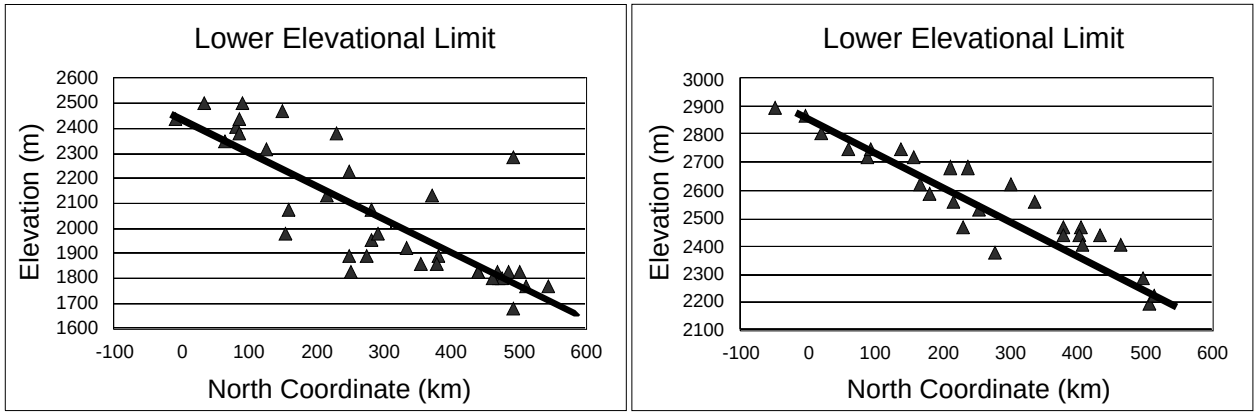

Figure 2—Scattergraphs of the lower (left) and upper (right) elevational livit of whitebark pine with the U.S.A. Albers North Coordinate. Regression lines are shown.

for ponderosa pine and whitebark pine ecosystems. Approximately 4,500 ha per year have been burning in the Bob Marshall Wilderness Area since 1980, albeit most were burned in two of those 15 years. Wilderness areas with intact fire regimes provide ideal laboratories to investigate large-scale ecosystem dynamics of whitebark pine.

The whitebark pine ecosystem is especially important to the wilderness recreational experience because its majestic form and picturesque surroundings are aesthetically pleasing to most wilderness travelers (Cole 1990; McCool and Friedman, in press). Many backpackers make whitebark pine forests their destination because they are typically open and park-like. The vistas are especially scenic because the forests are at high elevations where the wilderness traveler can view an entire wilderness landscape. Cole (1977) mentions that 46 percent of trail miles and 78 percent of campsites are in upper subalpine forest types. Many people cannot readily visit remote and inaccessible whitebark pine forests because it requires a physically demanding hike to reach these scenic ecosystems. Therefore, when they do visit, they are often captivated by the extraordinary beauty of the tree, the uniqueness of the surrounding stand, and the rugged, high mountain landscape. And since whitebark pine landscapes are diverse and open, it is relatively easy to hike off-trail and explore (Cole 1990). McCool and Friedman (in press) speculate on how the loss of whitebark pine in high mountain settings may detract from the wilderness experience. Therefore, these stately trees are not only crucial to the upper subalpine ecosystem, they also are important to wilderness beauty and the wilderness experience.

Whitebark pine ecosystems provide important food and habitat for many plant and animal species. Hutchins and Lanner (1982) documented over 110 wildlife species that utilize whitebark pine seed crops. In good cone years, whitebark pine seed comprises over 40 percent of the annual diet of Yellowstone grizzly bears (Mattson and others 1991). Nutcrackers and squirrels ultimately depend on whitebark pine seed to survive winter and spring food shortages (Mattson and Reinhart 1990; Tomback 1989). Open whitebark pine forests benefit many wildlife species because additional light increases undergrowth forage quality and berry production (Kendall and Arno 1990).

Table 1—Potential and existing whitebark pine extents (1000 x km^2) stratified by various land ownership and management categories (numbers in parenthesis are percent of total). These numbers are summarized for those States containing whitebark pine.

Land ownership	Existing whitebark pine map (state GAP maps)	Potential whitebark pine map (regression approach)	Whitebark pine range map Arno&Hoff 1990
Wilderness Areas and National Parks	4.6 (49)	27.1 (47)	69.3 (42)
National Forests	7.7 (82)	46.9 (81)	126.1 (76)
National Parks only	1.4 (15)	7.4 (13)	20.7 (13)
All Public lands	9.4 (99)	56.5 (98)	154.3 (94)
Private lands	0.1 (1)	1.1 (2)	10.6 (6)
Total	9.5 (100)	57.6 (100)	164.9 (100)

Wilderness Restoration: A Management Paradox? _____

Wilderness Whitebark Pine Status

Wilderness areas are not immune to the devastating effects of the exotic blister rust disease because of their remote settings or protected status. Many wilderness and roadless areas in the northern Rockies and Cascades containing five-needled pines have been experiencing rust-caused mortality for a half century or longer (Hoff and Hagle 1990). Blister rust spores are highly mobile, especially the wind-borne aeciospores, and can spread tens to hundreds of kilometers in a season, depending on winds and precipitation. Moreover, the rust will kill most whitebark pine trees regardless of tree vigor, ecosystem health or distance from humans, given enough time. Therefore, wilderness areas are no better protected from blister rust than any other high mountain landscape (Keane and others 1994; Kendall and Arno 1990).

There is little doubt that many wilderness areas are experiencing the same declines in whitebark pine as non-wilderness lands. Kendall and Arno (1990) estimate that over 90 percent of Glacier National Park's whitebark pine has died as a result of blister rust. Keane and others (1994) calculated that about 40 percent of the whitebark pine forests in the Bob Marshall Wilderness Complex has experienced over 50 percent rust-caused mortality. Keane and Arno (1993) remeasured 20-year old plots and found that whitebark pine stands in western Montana around the Selway-Bitterroot Wilderness Area have lost from 40 to 90 percent of whitebark pine basal area to blister rust and advancing succession. Smith and Hoffman (1998) also measured severe declines in both limber and whitebark pine in the southern parts of Idaho in roadless settings.

Unquestionably, human actions have directly (fire exclusion) and indirectly (rust epidemics) contributed to the decline of whitebark pine in and around wilderness areas. Even in the Selway-Bitterroot Wilderness Area, the annual area burned in whitebark pine forests is still less than 38 percent of the historical average (Brown and others 1994). Small wilderness areas atop isolated mountain ranges are especially vulnerable to fire suppression impacts because they are usually surrounded by private or public lands where fire suppression is practiced, so fire managers cannot allow fires to burn into the upper subalpine forests (Husari 1995; Murray and others 1998). As a result, the thin veil of pristineness has long been removed from many high mountain wilderness settings and it is doubtful the perceived pristine conditions will ever return. Fire exclusion has affected nearly every wilderness area in the western United States, and suppression of fires will undoubtedly continue. By removing the keystone disturbance of fire, we have essentially impeded or "trammeled" a critical natural processes. But we have the ability to reintroduce a semblance of historical fire effects in wilderness using prescribed fire. Herein lies the paradox: How do we minimize human influences in wilderness areas, while, at the same time, restore those ecosystem dynamics previously altered by humans. Ironically, restoration alternatives will inevitably require human intervention (Bonnicksen and Stone 1985).

Wilderness Whitebark Pine Restoration

Conservation of whitebark pine ecosystems will be nearly impossible without the reintroduction of fire to wilderness areas (Kilgore and Heinselman 1990). Nutcrackers like to cache whitebark pine seeds in openings, especially those created by fire (Tomback and others 1990). Moreover, germinated whitebark pine seeds have the best chance of growing to mature trees in burned areas because these areas are free of competition (McCaughey and Schmidt 1990). As fires are continually suppressed, no burned openings are created and secondary succession, accelerated by rust and beetle mortality, drives the rapid replacement of whitebark pine to subalpine fir and spruce. There is some natural genetic resistance in whitebark pine to the rust with about 1-5 percent of the population showing some mode of resistance. However, without burning, there will be fewer places where seeds from rust-resistant trees can be cached to grow into viable, seed-producing, rust-resistant individuals. Therefore, it appears the most important management action for conserving and maintaining vital whitebark pine ecosystems is to allow fires to burn in wilderness areas and play a more natural role in the ecosystem.

Some wildland fires have been allowed to burn in some wilderness areas since the late 1960's and early 1970's (Parsons and Landres 1998). Many land management agencies developed fire management plans to permit fires started by lightning to burn as long as weather and fuel moistures were within certain limits (that is, prescription). However, these fires, called prescribed natural fires, and more recently termed Wildland Fire for Resource Benefit (WFRB), only burned about 20,000 ha per year from 1972 to 1995 (Parsons and Landres 1998). At this rate, it would take over 2,100 years to burn an area equal to the entire wilderness system. The aftermath of the extensive 1988 fire season halted many wilderness fire programs and forced a national examination of fire policy (Elfring 1989). Only recently has the area burned from WFRB fires started to equal that burned prior to 1988 with over 30,000 ha burned in 1995 alone (Parsons and Landres 1998).

Restoration of whitebark pine ecosystems devastated by rust and fire exclusion may be problematic using treatments other than prescribed natural fires in many wilderness areas. Since most whitebark pine forests are found in remote roadless or wilderness settings with little road access, fire lines used in conventional prescribed fire are costly, damaging, difficult to construct and often in violation of the Wilderness Act of 1964. Silvicultural cuttings would be both difficult to justify due to wilderness regulations and expensive because of poor access, adverse site impacts, and low timber value. Extermination of rust from infected stands using aerial sprays is not a viable or preferred restoration alternative because it is expensive, ineffective and not ecologically sound (Brown 1969). Besides, new, wind-borne infections are always possible in the future, making it more important to have high levels of rust resistance in wilderness populations. Removal of the alternate rust host *Ribes spp.* by mechanical or herbicidal treatments was tried for 30 years but proved a non-viable means of controlling rust (Carlson 1978). Pruning infected branches may delay tree mortality, but ultimately, it is highly probable that future infections

will eventually kill the tree (Hoff and Hagle 1990; Hunt 1998). Since pruning and *Ribes* eradication are expensive, they are only feasible in localized, high-use areas, not in large wilderness areas (Dooling 1974; Hunt 1998). Therefore, it seems the best strategy to create the burned openings needed for whitebark pine regeneration in wilderness areas is prescribed fires. Natural breeding for rust resistance can be allowed to proceed as natural regeneration becomes established in burned openings because most seed will be harvested from rust-resistant trees (Hoff and Hagle 1990). Presently, the natural rust resistance breeding process is virtually stifled by fire exclusion.

There are many advantages of WFRB fires. First, ignitions usually occur during the summer, the season when most whitebark pine forests burned historically. Second, a summer ignition can be allowed to burn over many weeks, creating a mosaic of low to high severity fire patterns similar to historical whitebark pine fire burning patterns. Third, more area can be treated more inexpensively with WFRB's than with conventional prescribed fire because fire control structures are minimal and there are usually fewer people managing the fire. Fourth, large WFRB's can create large burned stands where only whitebark pine can colonize because of the long seed dispersal distances of the Clark's nutcracker. It may be easier to implement a stand-replacement fire using WFRB's because crown fires would be difficult to control using conventional prescribed fire techniques. Lastly, WFRB's are more socially acceptable. Their major disadvantage is they can quickly become uncontrollable wildfires because of long burning seasons, highly variable weather, and lack of control structures.

Prescribed natural fires (WFRB) may not be entirely effective in many wilderness whitebark pine forests because when whitebark pine forests are finally dry enough to burn, the adjacent lands in the low elevation forests are in high or extreme fire danger (Brown and others 1994; Kilgore and Briggs 1972). Fire managers will be reluctant to allow lightning fires to burn when only the whitebark pine forests are in prescription and the rest of the landscape is too dry. A possible solution is management-ignited prescribed fires where wilderness fires are ignited by fire crews when conditions are suitable (Brown 1992). Management-ignited prescribed fires have the added advantage of burning extensive areas in a short time, thereby taking advantage of the short-lived burning conditions in high mountain systems (Brown 1991; Keane and Arno 1996). Moreover, they may be the only feasible restoration tool for small wilderness areas where nearly every lightning fire poses potential risk to humans and property (Brown 1991; Husari 1995). Still, most wilderness fire plans do not allow management-ignited prescribed fires at present.

Many have criticized the concept of using management-ignited fires in wilderness areas because it appears unnatural and it has the stigma of human influence. But, extinguishing lightning strikes and actively fighting fires within a wilderness setting is arguably a larger scale trammeling of the wilderness ecosystem (Kilgore and Heinselman 1990). Furthermore, the most deadly factor contributing to whitebark pine decline is the human-introduced blister rust. This disease is rapidly eliminating a keystone species from several wilderness landscapes, and it has accelerated succession to create landscapes with high subalpine fir coverages well outside historical bounds (Keane and others 1994; Keane and Arno 1993; Murray and others 1998). Thus, the impact of this exotic disease, coupled with fire exclusion seems to have created unnatural wilderness landscapes. If naturalness is a wilderness character desired by the public, it seems logical that fire must be restored in wilderness settings to offset the damage done by introduced rust and advancing succession.

Conclusions

Whitebark pine is a keystone species of high mountain ecosystems in most wilderness areas of the northwest United States and western Canada. Wilderness areas are important to conservation of whitebark pine, and conversely, whitebark pine is important to wilderness integrity. Some of whitebark pine forests have recently been declining because of past mountain pine beetle epidemics, current introduced blister rust infections and the continued suppression of fire in wilderness areas. The key to conserving whitebark pine on the wilderness landscape is to allow fire to play its historical role as a recycling process. Fire creates open patches suitable for nutcracker caching and subsequent whitebark pine survival. Without fire, suitable openings for the caching of rust-resistant seeds will not be created, thereby stifling natural rust-resistance breeding processes. An active prescribed fire program for whitebark pine restoration is needed to restore declining ecosystems, but this program cannot rely only on lightning fires. Management-ignited wilderness fires will be needed to ensure adequate burned area because of 1) the large area needing treatment due to extensive rust and beetle epidemics, 2) the large area needed to bring high mountain landscapes back to ecologically suitable conditions after 70 years of fire suppression, and 3) the limited opportunity for prescribed burning from highly variable weather in the high-elevation ecosystems.

Conserving whitebark pine ecosystems may seem a daunting task, but many land management agencies have successfully developed large-scale prescribed fire programs (Parsons and Landres 1996). Some management organizations may want to get started on a smaller scale by implementing prescribed fire restoration projects in small stands to build up expertise and confidence. Not all whitebark pine ecosystems are in need of restoration. Severe sites where whitebark pine is the indicated climax species and sites in the southern parts of its range have not experienced significant rust mortality and adverse effects from fire exclusion, as yet. However, the rust seems to be expanding, and succession is a continual process (Keane and Arno 1994). One thing seems certain: Whitebark pine ecosystems will surely continue to decline if we continue with present management.

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References

Arno, S. 1979. Forest regions of Montana. USDA Forest Service Research Paper INT-218. 39 pages.

Arno, S. 1986. Whitebark pine cone crops—a diminishing source of wildlife food? W. Jour. of Applied Forestry 1:92-94.

Arno, S.; Hoff, R. 1990. *Pinus albicaulis* Engelm. Whitebark Pine. pp. 268-279. In: Silvics of North America. Vol. I. Conifers. USDA Forest Service Agricultural Handbook 654.

Arno, S.; Reinhardt, E.; Scott, J. 1993. Forest structure and landscape patterns in the subalpine lodgepole pine type: A procedure for quantifying past and present conditions. USDA Forest Service General Technical Report INT-294. 50 pages.

Arno, S. F.; Weaver, T. 1990. Whitebark pine community types and their patterns on the landscape. In: Schmidt W. C. and K. J. McDonald (Compilers), Proceedings — Symposium on Whitebark Pine Ecosystems: Ecology and management of a high mountain resource, March 29-31, 1989, Bozeman, MT. USDA Forest Service General Technical Report INT-270. Pages 118-130.

Baker, B. H.; Amman, G. D.; Trostle, G. C. 1971. Does the mountain pine beetle change hosts in mixed lodgepole and whitebark pine stands? USDA Forest Service Research Note INT-151. 7 pages.

Bonnicksen, T. M.; Stone, E. C. 1985. Restoring naturalness to national parks. Environmental Management 9:479-486.

Brown, D. H. 1969. Aerial application of antibiotic solutions to whitebark pine infected with cronartium ribicola. Plant Disease Reporter 53(6):487-489.

Brown, J. K. 1991. Should management ignitions be used in Yellowstone National Park. In: Keiter, R.B., M.S. Boyce (Editors) The Greater Yellowstone Ecosystem: Redefining America's Wilderness Heritage. Yale University Press, New Haven CN. Pages 137-146.

Brown, J. K. 1992. A case for management ignitions in wilderness. Fire Management Notes 53:3-8.

Brown, J. K.; Arno, S. F.; Barrett, S. W.; Menakis, J. P. 1994. Comparing the prescribed natural fire program with presettlement fires in the Selway-Bitterroot Wilderness. Int. J. Wildland Fire 4(3):157-168.

Carlson, C. E. 1978. Noneffectiveness of *Ribes* eradication as a control of white pine blister rust in Yellowstone National Park. Forest Insect and Disease Mgmt. Rep. 78-18. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region. 6 p.

Ciesla, W. M.; Furniss, M. M. 1986. Idaho's haunted forests. American Forests 81(8):32-35.

Cole, David N. 1977. Man's impact on wilderness vegetation: an example from Eagle Cap Wilderness, northeastern Oregon. Eugene OR: University of Oregon. Dissertation. 307 pages.

Cole, David N. 1990. Recreation in whitebark pine ecosystems: Demand, problems and management strategies. In: Schmidt W. C. and K. J. McDonald (Compilers), Proceedings — Symposium on Whitebark Pine Ecosystems: Ecology and management of a high mountain resource, March 29-31, 1989, Bozeman, MT. USDA Forest Service General Technical Report INT-270. Pages 305-310.

Cooper, S. V.; Neiman, K. E.; Roberts, D. W. 1991. Forest habitat types of northern Idaho: A second approximation. USDA Forest Service General Technical Report INT-236. 143 ages.

Czech, B. 1996. Challenges to establishing and implementing sound natural fire policy. Renewable Resources Journal 14(2):14-26.

Dooling, O. J. 1974. Evaluation of pruning to reduce impact of white pine blister rust on selected areas in Yellowstone National Park. USDA Forest Service Northern Region State and Private Forestry Report 74-19. 5 pages.

Elfring, C. 1989. Yellowstone: fire storm over fire management. Bioscience 39:667-672.

Ferner, J. W. 1974. Habitat relationships of *Tamiasciurus hudsonicus* and *Sciurus aberti* in the Rocky Mountains. Southwest Naturalist 18:470-473.

Forcella, F.; Weaver, T. 1980. Food production in Pinus albicaulis-Vaccinum scoparium association. Proceedings of Montana Academy of Scince 39:73-80.

Habeck, James R. 1970. Fire ecology investigations in Glacier National Park — Historical considerations and current observations. USDI National Park Service Final Report on file at Glacier National Park, West Glacier, Montana. 80 pages.

Habeck, James R. 1985. Impact of fire suppression on forest succession and fuel accumulations in long-fire-interval wilderness habitat types. In: Lotan, James E.; Kilgore, Bruce M.; Fisher, William C.; Mutch, Robert W., technical coordinators. Proceedings-Symposium and Workshop on Wilderness Fire; 1983 November 15 - November 18; Missoula, MT. General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 110-118.

Hann, Wendal J. 1990. Landscape and ecosystem-level management in whitebark pine ecosystems. In: Schmidt W.C. and K.J. McDonald (Compilers). Proceedings - Symposium on Whitebark pine ecosystems: Ecology and management of a high mountain resource. Pages 335-340. March 29-31, 1989, Bozeman, Montana. USDA Forest Service General Technical Report INT-270.

Hoff, Raymond; Bingham, Richard; MacDonald, Geral J. 1980. Relative blister rust resistance of white pines.European J. For. Pathology. 10:307-316.

Hoff, Raymond; Hagle, Sue. 1990. Diseases of whitebark pine with special emphasis on white pine blister rust. In: Schmidt W.C. and K.J. McDonald (Compilers). Proceedings—Symposium on Whitebark pine ecosystems: Ecology and management of a high mountain resource. Pages 335-340. March 29-31, 1989, Bozeman, Montana. USDA Forest Service General Technical Report INT-270.

Hunt, R. S. 1998. Pruning western white pine in British Columbia to reduce white pine blister rust losses: 10-year results. Western Journal of Applied Forestry 13(2):60-64.

Hutchins, H. E.; Lanner, R. M. 1982. The central role of Clark's nutcrackers in the dispersal and establishment of whitebark pine. Oecologia, 55:192-201.

Husari, Susan J. 1995. Fire management in small wilderness areas and parks. In: Brown, J.K.; Mutch, R.W.; Spoon, Charles W.; Wakimoto, Ronald H. Tech coords. 1995. Proceedings: symposium on fire in wilderness and park management; 1993 March 30-April 1; Missoula, MT. General Technical Report INT-GTR-20. Ogden, UT; US Dept of Agriculture, Forest Service, Intermountain Research Station. Pages 117-120.

Keane, R.E. (In press). Successional Dynamics: Modeling an Anthropogenic Threat. In: Tomback, D.F., S.F. Arno, R.E. Keane (editors) Restoring whitebark pine ecosystems. Island Press, Arizona.

Keane, R. E.; Arno, S. F.; Brown, J. K.; Tomback, D. F. 1990. Modeling disturbances and conifer succession in whitebark pine forests. pp. 274-288. In: Proceedings—symposium. Whitebark pine ecosystems—ecology and management of a high mountain resource. USDA Forest Service General Technical Report INT-270. 33 pages.

Keane, R. E.; Arno, S. F. 1993. Rapid decline of whitebark pine in western Montana: Evidence from 20-year remeasurements. W. Jour. of Applied Forestry 8(2):44-47.

Keane, R. E.; Morgan, P.; Menakis, J. P. 1994. Landscape assessment of the decline of whitebark pine (*Pinus albicaulis*) in the Bob Marshall Wilderness Complex, Montana, USA. Northwest Science 68(3):213-229.

Keane, R. E.; Arno, S. F. 1996. Whitebark Pine (*Pinus albicaulis*) ecosystem restoration in western Montana. In: Arno, S.F. and Hardy, C.C., editors, The use of fire in forest restoration, a general session at the annual meeting of the Society of Ecosystem Restoration "Taking a broader view". Sept 14-16, University of Washington, Seattle, WA. USDA Forest Service General Technical Report INT-GTR-341. Pages 51-54.

Keane, R. E.; Menakis, J. P.; Hann, W. J. 1996. Coarse scale restoration planning and design in Interior Columbia River Basin Ecosystems—An example using Whitebark Pine (*Pinus albicaulis*) forests. In: Arno, S.F. and Hardy, C.C., editors, The use of fire in forest restoration, a general session at the annual meeting of the Society of Ecosystem Restoration "Taking a broader view". Sept 14-16, University of Washington, Seattle, WA. USDA Forest Service General Technical Report INT-GTR-341. Pages 14-20.

Kendall, K. C.; Arno, S. F. 1990. Whitebark pine—an important but endangered wildlife resource. Proceedings of the symposium: Whitebark pine ecosystems: Ecology and management of a high mountain resource, March 29-31, 1989, Bozeman, Montana, USA. USDA Forest Service General Technical Report INT-270. Pp. 264-274.

Kilgore B. M.; Briggs, G. W. 1972. Restoring fire to high elevation forests in California. Journal of Forestry 70:266-271.

Kilgore, B. M.; Heinselman, M. L. 1990. Fire in wilderness ecosystems. In: Hendee, J.C., G.H. Stankey, and R.C. Lucas (editors) Wilderness Management. North American Press, Golden Colorado. Pages 297-335.

Lasko, R. J. 1990. Fire behavior characteristics and management implications in whitebark pine ecosystems. In: Schmidt, W.C. and K.J. McDonald (Compilers), Proceedings—Symposium on whitebark pine ecosystems: Ecology and management of a high-mountain resource. USDA Forest Service General Technical Report INT-270. Pages 319-324.

Little, E. L. 1971. Atlas of United States trees: Volume One. Conifers and important hardwoods. USDA Forest Service Misc. Publ. 1146. Washington D.C. (Pages not numbered)

Mattson, D. J.; Blanchard, B. M.; Knight, R. R. 1991. Food habits of Yellowstone grizzly bears, 1977-1987. Canadian Journal of Zoology. 9:1619-1629.

Mattson, D. J.; Reinhart, D. P. 1990. Whitebark pine on the Mount Washburn Massif, Yellowstone National Park. In: Schmidt, W.C. and K.J. McDonald (compilers): Proceedings—Symposium on whitebark pine ecosystems: Ecology and management of a high-mountain resource. March 29-31, 1989, Bozeman, Montana. USDA Forest Service General Technical Report INT-270. Pages 106-117.

McCaughey, Ward W.; Schmidt, W.C.; Shearer, R.C. 1985. Seed dispersal characteristics of conifers of the Inland Mountain West. In: R.C. Shearer (compiler). Proc. Symp. Conifer Seed in Inland Mountain West, 5-6 April 1985, Missoula, MT, pp. 50-61.

McCaughey, W. W.; Schmidt, W. C. 1990. Autecology of whitebark pine. In: W. C. Schmidt and K. J. McDonald (compilers): Proceedings—Symposium on whitebark pine ecosystems: Ecology and management of a high mountain resource. March 29-31, 1989, Bozeman, Montana, USA. USDA Forest Service General Technical Report INT-270. Pp. 85-95.

McCaughey, Ward W.; Weaver, T. 1990. Biotic and microsite factors affecting whitebark pine establishment. Proceedings of the symposium: Whitebark pine ecosystems: Ecology and management of a high mountain resource, March 29-31, 1989, Bozeman, Montana, USA. USDA For. Serv. Gen. Tech. Rep. INT-270. Pp. 140-151.

McCool, Stephen F.; Freimund, Wayne. (In Press). Aesthetic and recreational consequences: A diminished landscape. In: Tomback, D. F., S. F. Arno, R. E. Keane (editors) Restoring whitebark pine ecosystems. Island Press, Arizona.

Minore, D. 1979. Comparative autecological charateristics of northwestern tree species: a literature review. USDA Forest Service General Technical Report PNW-87. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 28 p.

Morgan, P.; Bunting, S. C.; Keane, R. E.; Arno, S. F. 1994. Fire ecology of whitebark pine (*Pinus albicaulis*) forests in the Rocky Mountains, USA. In: W.Schmidt and F.Holtzmeier (Compilers) Proceedings of the international symposium Subalpine stone pines and their environment: The status of our knowledge, St. Moritz, Switzerland. Sept. 5-11, 1992. Pages 136-142.

Murray, M. P.; Bunting, S. C.; Morgan, P. 1998. Fire history of an isolated subalpine mountain range of the Intermountain Region, United States. Journal of Biogeography 25:1071-1080.

Norment, C. J. 1991. Bird use of forest patches in the subalpine forest-alpine tundra ecotone of the Beartooth Mountains, Wyoming. Northwest Science 65(1):1-10.

Parsons, D. J.; Landres, P. B. 1998. Restoring natural fire to wilderness: How are we doing? Tall Timbers Fire Ecology Conference Proceedings 20:366-373.

Perkins, D. L.; Swetnam, T. W. 1996. A dendroecological asessment of whitebark pine in the Sawtooth-Salmon River region, Idaho. Canadian Journal Forest Research 26:2123-2133.

Pfister, Robert D.; Kovalchik, B. L.; Arno, S. F.; Presby, R. C. 1977. Forest habitat types of Montana. Gen. Tech. Rep. INT-34. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 174 p.

Redmond, Roland L.; Prather, Martin L. 1996. Mapping existing vegetation and land cover across western Montana and north Idaho. Report on file at: U.S. Department of Agriculture, Forest Service, Northern Region, Ecosystem Management. P.O. Box 7669, Missoula, MT. Contract 53-0343-4-000012. 211 pages.

Rogeau, M. P. 1996. Understanding age-class distributions in southern Canadian Rockies. MS thesis, University of Alberta, Edmonton, Alberta. 123 pages.

Smith, J.; Hoffman, J. 1998. Status of white pine blister rust in Intermountain Region white pines. USDA Forest Service Forest Health Protection Report No. R4-98-02. Intermountain Region State and Private Forestry, Ogden, UT.

Steele, R.; Cooper, S. V.; Ondov, D. M.; Roberts, D. W.; Pfister, R.D. 1983. Forest habitat types of eastern Idaho-western Wyoming. USDA Forest Service General Technical Report INT-144. 122 pages.

Sund, S. K.; Tomback, D. F.; Hoffman, L. 1991. Post-fire regeneration of *Pinus albicaulis* in western Montana: Patterns of occurrence and site charactertistics. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Intermountain Fire Sciences Laboratory, Missoula, MT. 55 p.

Tomback, D. F. 1989. The broken circle: fire, birds and whitebark pine. In: T. Walsh (editor), Wilderness and Wildfire. University of Montana, School of Forestry, Montana Forest and Range Experiment Station Misc. Pub. 50. Pages 14-17.

Tomback, D. F. 1998. Clark's Nutcracker (*Nucifraga columbiana*). *In*: The Birds of North America, No. 331 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA. 24 pages.

Tomback, D. F.; Hoffman, L. A.; Sund, S. K. 1990. Coevolution of whitebark pine and nutcrackers: Implications for forest regeneration. In: Proceedings of the symposium: Whitebark pine ecosystems: Ecology and management of a high mountain resource, March 29-31, 1989, Bozeman, MT. Gen. Tech. Rep. INT-270. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 118-130.

Tomback, D. F.; Sund, S. K.; Hoffman, L. A. 1993. Post-fire regeneration of *Pinus albicaulis*: height-age relationships, age structure, and microsite characteristics. Canadian Journal of Forest Research 23:113-119.

Weaver, T.; Dale, D. 1974. *Pinus albicaulis* in central Montana: Environment, vegetation, and production. American Midland Naturalist 92:222-230.

Alpine Vegetation Communities and the Alpine-Treeline Ecotone Boundary in New England as Biomonitors for Climate Change

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Abstract—This study mapped and analyzed the alpine-treeline ecotone (ATE) boundary and alpine plant communities on the Presidential Range, New Hampshire and Mount Katahdin, Maine. These are sensitive biomonitoring parameters for plant community responses to climatic change. The ATE boundary spans a considerable elevational range, suggesting that shorter growing seasons with increasing elevation only partially explain the upper limits for this boundary. This ecotone boundary may be influenced by topographic exposure factors related to mechanical damage caused by winter ice events and wind. Climatic changes that alter cloud frequency, wind, precipitation and ice loading at the upper elevations could influence shifts in the ATE boundary.

The ecological and societal implications of major geographic shifts in vegetation as a response to climatic change are profound. There are many competing hypotheses about whether climatic change is occurring and the reasons for it. These include natural events such as variations in solar irradiation (Karlan 1998) to the increased accumulation of greenhouse gases of anthropogenic origin (Gates 1993). The long-term objective of the National Oceanic Atmosphere Administration's (NOAA) Climate and Global Change Program is to provide reliable predictions of global climatic change and associated regional implications on time scales ranging from 10 to 100 years. This study establishes a biomonitoring baseline for plant community shifts due to climatic variability, based on the alpine-treeline ecotone (ATE) boundary in the Northeast. Long-term climatic conditions have altered since the retreat of the Pleistocene glaciers and climatic changes will continue to affect the ecotone boundary between the alpine zone and treeline in this region.

In the United States east of the Mississippi River, alpine habitat is currently a relatively rare habitat, occurring mostly as isolated islands on higher peaks. In total, it is estimated to occupy at most about 34 km^2. The majority of this alpine habitat is located on New Hampshire's Presidential Range (11.3 km^2), and Mount Katahdin, Maine (7.3 km^2) (fig. 1). The remaining Eastern alpine areas are limited to several hundred hectares or less in size in northern New York, Vermont, New Hampshire, Maine and southward along the Appalachian Mountain Range. There are characteristics that make northeastern "alpine" mountains suited to the monitoring of vegetation responses to climatic change. They are mostly in public ownership and have relatively undisturbed histories. Their alpine plant communities have been relatively stable for extended periods of time because the dominant species are mostly long-lived perennials. The isolated nature of these particular alpine zones limits disease and herbivore impacts. Proximate weather data are also available to describe existing climatic conditions.

Spatial Changes in the Alpine-Treeline Ecotone as a Barometer of Climatic Change

Spatial changes in the ATE boundary and the alpine vegetation communities have the potential to be sensitive indicators of vegetative response to climate change. In 1941, Griggs (1942) gave an address at a "Symposium on Alpine Ecology" to the Ecological Society of America, in which he

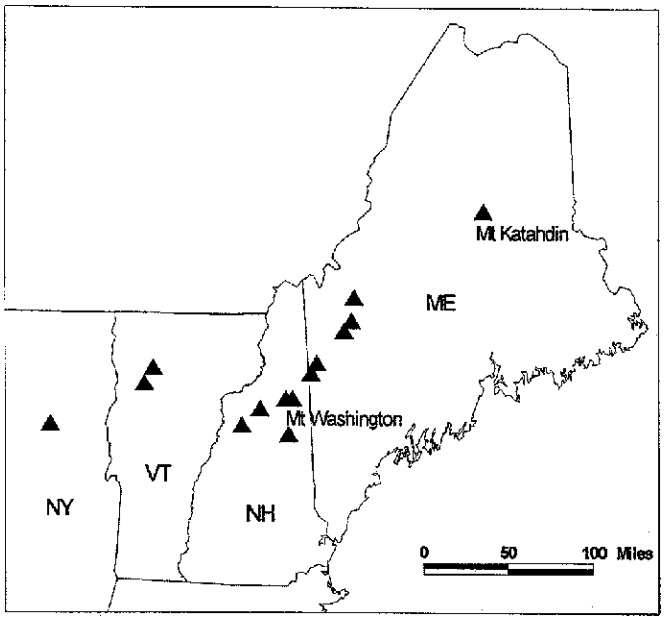

Figure 1—Study area and alpine areas in the northeastern United States.

In: McCool, Stephen F.; Cole, David N.; Borrie, William T.; O'Loughlin, Jennifer, comps. 2000. Wilderness science in a time of change conference—Volume 3: Wilderness as a place for scientific inquiry; 1999 May 23–27; Missoula, MT. Proceedings RMRS-P-15-VOL-3. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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reviewed the dynamic history of treeline on Mount Washington, New Hampshire since glacial retreat. His concern was the change in the climate towards a repeat of colder conditions again causing a "further" retreat of treeline on this mountain. Today, more than a half century later, changes in our earth's atmosphere create the possibility of a very different scenario, global warming due to 'greenhouse' gas emissions.

Temperature-limited environments, such as boreal and arctic regions, are thought to be very sensitive to global warming. Grabherr and others (1994) reported an upward elevation migration of the alpine-nival (uppermost) flora from their 1992 field work in the mountains exceeding 3,000 m of western Austria and eastern Switzerland, compared to 70–90 years before, a change they linked to climatic warming. They concluded that an upward altitudinal shift in the alpine vegetation belt could theoretically be occurring at a rate of 8-10 m per decade. Myneni and others (1997) reported increased plant growth from 1981 to 1991 in the northern arctic latitudes and related it to increased CO_2 levels and warmer temperatures. Similarly, Gottfreid and others (1998) hypothesized that the alpine-nival ecotone boundary in the European Alps will probably be affected by climatic change, but that the vegetation patterns at this interface zone will also be related to topographic relief.

Relationship of Alpine Vegetation Communities to Topographic Exposure Factors

Topographic relief can modify a mountain's climate considerably. In Northeastern alpine areas, topographic features of exposure may interact with climate as a dominant factor in treeline and the distribution of alpine plant communities. Climate change probably takes place more quickly than major overall topographic changes on Northeastern mountains. Climate change could, therefore, significantly alter the distribution of alpine plant communities. Determinants for the distribution of alpine plant communities and the ATE boundary should include climate, as well as topographic features of exposure including elevation, aspect, slope and slope shape, e.g. concavity (valley) or convexity (ridge). Clearly, there are other factors as well, including edaphic conditions and the biogeography of species in island habitats.

The Presidential Range is located at the convergence of weather derived from three different air masses, which give rise to frequent cloud events and strong winds. For the Presidential Range, the frequency of clouds by elevation commonly approximates the treeline boundary. The summit of Mount Washington is in the clouds over 55% of the time. During the winter, rime ice deposition, caused by enshrouding clouds propelled by strong winds, can give rise to heavy mechanical loading and subsequent damage to the vegetation. Blowing snow on the mountains has considerable abrasive action before it is blown off the more exposed alpine zone and deposited in the ravines and snowfields.

Bliss (1963) attributed the distribution of nine plant community types on Mount Washington to two gradients: 1) an increasing snow depth and late spring melt gradient, and 2) increasing summer atmospheric and soil moisture and fog. Bliss suggested that these moisture gradients are strongly influenced by topographic features of aspect and elevation. The first objective of this study is to quantify the availability of different topographic features and how they relate to the frequency and distribution of different alpine plant communities on the Northeast's higher mountains. A second objective is to better understand how the ATE boundary and alpine plant communities, as biomonitoring parameters, may respond to climatic change.

Study Sites

Protected within the White Mountain National Forest, the highest peak of the Presidential Range is Mount Washington, at 1917 m. Though the alpine zone of this range has seen considerable human use over two centuries (Randall 1983), it is still relatively undisturbed. It is the largest and most ecologically diverse alpine zone in the Northeast. The Great Gulf and Presidential Dry River Wildernesses extend upwards into this alpine zone. There have been earlier studies on vegetation patterns and forest migration on the lower slopes of the Presidential Range (Foster and Reiners 1983; Leak 1975; Leak and Graber 1974; Kimball and Keifer 1988; Worrall and Harrington 1988); Spear's (1981) attempt to reconstruct the post-glacial changes in the high-elevation vegetation also provides considerable insight. Although logging occurred on the lower slopes at the turn of the century (Belcher 1980), the upper slopes of the Presidential Range for the most part were not logged due to difficult access.

The weather has been well documented on Mount Washington's summit; meteorological observations occurred there from 1870-1887 and then in summer only until 1892. Daily weather observations have now been taken since 1933 by the Mount Washington Observatory. The Appalachian Mountain Club has also maintained a weather station on the eastern slope at 620 m since 1933. Both sites are part of the National Weather Service network.

The Mount Katahdin Range lies within Baxter State Park with Mount Katahdin as its highest peak at 1605 m. This State Park is managed under a forever "natural wild state" mandate according to the wishes of its donor, Governor Percival Baxter. Similar to the Presidential Range, timbering encroached on the lower slopes of the Kathadin Range prior to its purchase in 1930 (Clark 1996), but the upper slopes were less affected (Hudson and others 1985). A meteorological record does not exist for Mount Katahdin and must be inferred from surrounding low-elevation monitoring sites.

Methods

Field Mapping

The subalpine and alpine vegetation communities of the Presidential Range were field-mapped during 1991-1993. Seventeen, uncorrected, color aerial photographs (Aug. 19, 1978 at 1:12,000 scale, then enlarged to 1:5,000) were used as the mapping base layer. In the field, mappers outlined and coded the dominant vegetation community types on the mylar-covered photos. The minimum mapping unit was 100 m^2. Vegetation community classifications were krummholz,

Table 1—Area for each community type within the alpine zone for the Presidential and Katahdin Ranges.

	Presidential Range		Katahdin Range	
	Area (ha)	% total	Area (ha)	% total
Krummholz	73	7	23	3
Birch-alder	2	<1	6	1
Heath-shrub-rush	115	10	245	34
Cushion-tussock	94	8	34	5
Sedge meadow	80	7	2	<1
Herbaceous snowbank	3	<1	4	1
Fellfield	759	67	312	43
Cliff	N/A	—	102	14
Other	6	1	0	0
Total	1132	100	728	100

birch-alder, fellfield, sedge meadow, heath-shrub-rush, herbaceous snowbank and cushion-tussock. The dominant plant species and a comparison to related natural community nomenclature in the literature are given in table 1.

Field mapping on the Mount Katahdin Range was conducted during 1998 using 1991 color infrared, aerial photographs (1:40,000 scale, then orthorectified to a scale of 1:3,000). Vegetation community classification units were the same as those from the Presidential Range, with the exception of an additional cliff category.

Vegetation Mapping and Orthorectification

For the Presidential Range, vegetation polygons were digitized in vector form using Atlas Draw, and rasterized to 3 m pixels in IDRISI. Geometric rectification of these vegetation maps was necessary. To orthorectify the Presidential Range vegetation maps, latitude, longitude, and elevation of ground control points were collected with a global positioning system, and with United States Geological Survey Digital Elevation Model (USGS DEM) data run through an orthophoto procedure. Orthorectification accuracy of the Presidential Range vegetation maps (aerial photos) is estimated to be 15 m. Katahdin Range vegetation polygons were digitized with CartaLinx and rasterized to 3 m pixels, similar to the Presidential Range study.

In this study, krummholz and birch-alder occur in both the subalpine and alpine zone. We define the lower limits of the subalpine forest as areas where the trees are less than 2.5 m in height. Accurately mapping the lower elevation subalpine forest boundary was problematic: It was difficult to define the boundary where trees were 2.5 m high, and the field mappers were unable to accurately locate themselves on the aerial photos in the dense cover. Reference points along hiking trails and other easy access points were used to define the lower subalpine forest zone, and professional judgement was used to interpolate.

Where birch-alder and krummholz community types abut or merge with the true alpine zone and extend down into the subalpine forest, we arbitrarily excluded them and used their uppermost limit as the start of the alpine zone boundary for purposes of calculating the area of the alpine zone. If these community types were totally enclosed within the alpine zone, they were included as alpine. Where cliff and fellfield were totally contained within the subalpine zone, they were included as part of the subalpine zone.

DEM and Environmental Variables

The 30 m USGS DEM images used for the Presidential Range were resampled to 3 m pixels using nearest neighbor calculation. The DEM source data contained "streaking" artifacts in the data. We tried a filtering command within IDRISI to enhance the source DEM data. This did not completely remove the artifacts within the source DEM data and, unfortunately, eliminated extreme values like steep slopes. Therefore, we used the DEM data without filtering.

The elevation model for the Katahdin Range was based on source USGS 1:24,000 contour data and constructed into a DEM with a pixel resolution of 10 m by James W. Sewall Company, which we resampled to 3 m.

The vegetation layers were geo-referenced with four environmental variables derived from Digital Elevation Model (DEM) data—elevation, aspect, slope percent and slope shape (concave to convex). These parameters are assumed to be important exposure factors that influence microclimate and alpine plant distribution. Elevation comes directly from the DEM, while aspect and slope percent were generated with the IDRISI SURFACE command (Eastman 1992).

The slope shape is a relative index that estimates concavity and convexity across 570 meters on the ground. It was calculated by applying a convolution filter to the DEM image with a 191 x 191 pixel kernel that had –1 as the coefficient at the N,S,E and W positions in the kernel (the middle of each side), 4 at the middle (target pixel), and 0 everywhere else, with a gain of 0.08772. The resulting values represent the average of the slope percentage from the target pixel in each of the four compass directions at a distance of 285 m. Negative values represent increasing concavity (valley), positive values represent increasing convexity (ridge), and a plane is represented by a zero value.

Statistical Analysis

For each alpine plant community and the entire study area, total area, as well as mean, standard deviation, minimum and maximum elevation, slope percent and slope shape were calculated. A common but often incorrect practice in the ecological literature is to treat aspect as a linear variable, instead of a circular variable. This treatment of aspect can result in incorrect results (for example, the average aspect for 350 and 10° should be 0°, not 180°). To alleviate this problem, we used circular statistics (Batschelet 1981) to calculate the mean angle and mean angular deviation (equivalent to the standard deviation of linear statistics) for aspect; minima and maxima appropriately were not calculated.

The distributions of elevation, slope percent and slope shape for each alpine plant community were compared to their total available distribution across the entire study area, using Kolmogorov-Smirnov two sample tests (SYSTAT 1996) to determine significant differences. The aspect data was placed into eight groups (N, NE, E, etc.) to moderate a bias towards all multiples of 45 degrees generated by the IDRISI aspect model. A chi-squared test was performed

comparing the grouped aspect distribution of each alpine plant community against the available grouped distribution.

Results and Discussion

Alpine Plant Communities

The Presidential Range subalpine and alpine zone covers 2,748 ha: subalpine and alpine krummholz (1,351 ha, 49%), fellfield (867 ha, 32%), birch-alder community (226 ha, 8%), heath-shrub-rush (115 ha, 4%), cushion-tussock (94 ha, 3%), sedge meadow (80 ha, 3%), and herbaceous snowbank (3 ha, <1%). The Mount Katahdin Range covers 1,697 ha: subalpine and alpine krummholz (723 ha, 43%), fellfield (349 ha, 21%), heath-shrub-rush (245 ha, 14%), birch-alder (219 ha, 13%), cliff (117 ha, 7%), cushion-tussock (34 ha, 2%), herbaceous snowbank (4 ha, <1%) and sedge meadow (2 ha, <1%). The noticeable difference between the two mountains is the greater degree of cliffs, but limited presence of sedge meadows on the Katahdin compared to the Presidential Range. Table 1 shows vegetation community-type composition only within the alpine zone. Large-scale color maps of the subalpine-alpine vegetation communities were developed for future monitoring.

The classification system used in this study is similar to other studies that have looked at plant communities found in the larger New England alpine areas (table 2), although differences exist. Due to the scale of this study, localized or narrow linear communities were not included, therefore we excluded alpine streamside vegetation. Other investigators have not included birch-alder or fellfield as alpine plant communities. Bliss (1963) refers to felsenmeer as a geological phenomena rather than an alpine plant community type, while Cogbill and Hudson (1990) do not include it in any of their transects. We included fellfield because, in addition to extensive lichen colonies on the rocks, the interstitial spaces between the rocks harbor considerable vegetation: and also fellfield occupies a dominant part of the alpine zone in our study area. Birch-alder communities are largely a result of past landslides or snowslides, which create a suitable environment for these pioneering species (Flaccus 1959). Depending on the frequency of these disturbances, the birch-alder community may be a transient alpine community on its way to being re-established as a boreal spruce-fir community, or it may be a more permanent subalpine plant community devoid of tall vegetative growth.

Elevation

The distribution by elevation of the different plant communities is summarized in table 3 for the Presidential Range and table 4 for the Katahdin Range. Most plant communities spanned an elevation gradient of 500-750 m, except the sedge meadow and cushion tussock communities on the Katahdin Range, which ranged from 172-380 m. Bliss (1963), Marchand (1987) and Sperduto (1994) have placed sedge meadow and cushion-tussock communities among the highest elevations within the alpine environment. Our data support this premise for the sedge meadow, but less so for the cushion-tussock community. The lower elevation of the birch-alder community may be part of the reason these authors do not include it in their montane classification systems. Krummholz has the second lowest mean elevation.

There is an approximate 250 m elevation shift of all the plant communities we studied between the two ranges, with all found lower on the Katahdin Range. We attribute this to the Katahdin Range being 1°38' latitude (ca. 180 km) farther north then the Presidential Range.

Slope

The slopes of the vegetation communities for the study areas are listed in tables 2 and 3. Cushion-tussock and sedge meadow communities are generally found on more moderate slopes, whereas the birch-alder community is generally found on the steeper, slide-prone slopes.

Aspect

The Presidential Range encompasses areas facing all aspects but contains a southern bias, while the Katahdin Range has a bias towards the west (tables 3 and 4). The sedge community tends to the northwest on both mountain ranges. This directional orientation of the sedge meadow community corresponds to that described by Bliss (1963), Marchand (1987) and Sperduto (1994), which could be related to moist air masses being uplifted, cooled and then depositing greater amounts of cloud water and precipitation on the windward side of the range. On both mountain ranges, birch-alder tends somewhat to the northeast, which may relate in part to how winds deposit snow blown off the alpine area, causing periodic avalanches. The herbaceous snowbank community shows some directional orientation towards the east to southeast, which supports statements by Bliss (1963), Marchand (1987), and Sperduto (1994) that the herbaceous snowbank community is often found on east to southeast slopes. Again, this may in part be due to how leeward winds deposit snow blown off the exposed alpine area.

Slope Shape (Concave or Convex)

Overall, the mean shape index for both study areas is slightly convex (tables 3 and 4), which is to be expected for a mountain. The birch-alder and, to a less degree, the herbaceous snowbank community tend toward a concave value on both mountain ranges. Bliss (1963), Marchand (1987) and Sperduto (1994) have pointed out the importance of deep, late-melting snowbanks in protecting plants of the species-rich herbaceous snowbank community from fluctuating temperatures during the late spring. The generally concave microhabitat of the herbaceous snowbank community allows for greater accumulation of snow. All other plant community means were convex. The cushion-tussock community tends strongly towards convexity and occupies the other end of the spectrum in terms of snow depth. It is found on exposed wind-blown areas, where there is little or no snow cover (Bliss 1963; Tiffney 1972; Day 1984).

Statistical Analyses

Kolmogorov-Smirnov goodness-of-fit tests indicate that, individually, the elevation, slope and shape index distribution of

Table 2—Alpine plant community nomenclature and dominant plant species.

AMC	Cogbill and Hudson (1990)	Sperduto (1994) NHNHI	Bliss (1963)	Dominant species	Potentially common species
Krummholz	Krummholz	Subalpine Krummholz	Krummholz	*Abies balsamea* (balsam fir) *Picea mariana* (black spruce)	Highly variable. Influenced by surrounding communities and changes in microclimate and topography
Birch-Alder	None	None	None	*Betula papyrifera* (paper birch) *Alnus crispa* (mountain alder)	*Abies balsamea* *Picea mariana*
Fellfield	None	Fellfield	Felsenmeer	*Rhizocarpon geographicum* (map lichen) *Parmelia centrifuga* (ring lichen) *Umbilicaria hyperborea* (rock tripe)	Highly variable. Influenced by changes in microclimate and topography.
Sedge Meadow	Sedge Meadow	Heath-Meadow (Sedge Meadow association)	Sedge Meadow	*Carex bigelowii* (Bigelow's sedge)	*Arenaria groenlandica* (mountain sandwort) *Vacc. vitus-idaea* (mountain cranberry) *Vacc. uliginosum* (alpine bilberry)
		Heath-Meadow (Sedge-Heath-rush association)	Sedge-Dwarf Shrub Heath Sedge-Rush-Dwarf Shrub Heath	*Carex bigelowii* *Juncus trifidus* (highland rush)	*Vacc. vitus-idaea* *Vacc. uliginosum* *Potentilla tridentata* (three-toothed cinquefoil) *Arenaria groenlandica*
Heath-Shrub-Rush	Alpine Heath	Heath-Meadow (Heath-Rush)	Dwarf Shrub Heath-Rush	*Vacc. vitus-idaea* *Vacc. uliginosum* Juncus trifidus	*Potentilla tridentata*
		Heath Snowbank	Dwarf Shrub Heath	*Ledum groenlandicum* (Labrador tea) *Vacc. vitus-idaea* *Vacc. uliginosum* *Empetrum nigrum* (black crowberry)	*Cassiope hypnoides* (cassiope) *Loisleuria procumbens* (alpine azalea) *Phyllodoce caerulea* (phyllodoce) *Arctostaphyllos alpina* (alpine bearberry)
Herbaceous Snowbank	Snowbank	Herbaceous Snowbank Meadow	Snowbank	*Deschampsia flexuosa* (hairgrass) *Solidago cutleri* (Cutler's goldenrod) *Vacc. caespitosum* (dwarf bilberry) *Houstonia caerulia** (alpine bluets) *Vacc. uliginosum*	*Veratrum viride* (false hellebore) *Clintonia borealis* (blue-bead lily) *Geum peckii** (mountain avens) *Phleum alpinum* (alpine timothy) *Castilleja septentrionalis* (pale painted cup)
Cushion-Tussock	Diapensia	Diapensia	Diapensia	*Diapensia lapponica* (diapensia) Juncus trifidus *Rhododendron lapponicum* (Lapland rosebay) *Loisleuria procumbens* *Vacc. Uliginosum*	*Solidago cutleri* *Salix uva-ursi* (bearberry willow) *Agrostis borealis* (boreal bentgrass) *Arenaria groenlandica*

(con.)

Table 2—(Con.)

AMC	Cogbill and Hudson (1990)	Sperduto (1994) NHNHI	Bliss (1963)	Dominant species	Potentially common species
None	None	Alpine Streamside	Alpine Streamside	*Salix planifolia* (tea-leaved willow) *Salix argyrocarpa* (silver willow) *Salix herbacea* (dwarf willow)	*Calamagrostis pickeringii* (Pickering's reed bent-grass) *Cardamine bellidifolia* (alpine bitter-cress) *Saxifraga rivularis** (alpine brook saxifrage) *Epilobium hornemanni* (Hornemann's willow herb) *Viola palustris* (alpine marsh violet)
Water	None	Alpine/ Subalpine Bog	Alpine Bog	*Rubus chamaemorus** (cloudberry) *Betula glandulosa* (dwarf birch) *Empetrum atropurpureum* (purple crowberry) Empetrum nigrum	Geocaulon lividum (northern comandra) *Vacc. uliginosum*
Cliff	None	Alpine Cliff	None	*Diapensia lapponica* *Empetrum atropurpureum* *Empetrum nigrum*	*Carex scirpoidea* (scirpus-like sedge) *Solidago cutleri*
		Alpine Cliff/ Seep		*Geum peckii** *Houstonia caerulea** *Calamagrostis neglecta* (neglected reedgrass)	*Cardamine bellidifolia* *Saxifraga rivularis** *Epilobium hornemann*i

*Not found on Katahdin Range.

Table 3—Descriptive statistics of exposure factors for each subalpine/alpine community type on the Presidential Range, NH. The slope shape index is a relative scale where increasing positive values represent increasing convexity, increasing negative values represent increasing concavity, and a plane is represented by the value 0.

	Birch-alder	Cushion-tussock	Herbaceous snowbank	Krummholz	Fellfield	Sedge meadow	Heath shrub-rush	All
Elevation (m)								
Mean	1375	1565	1562	1450	1596	1680	1534	1504
Std. Dev.	110	77	75	98	127	97	115	136
Max.	1624	1851	1716	1735	1909	1901	1838	1909
Min.	881	1233	1183	1056	1029	1345	1170	881
Slope Shape								
Mean	-2	13	0	4	8	8	10	5
Std. Dev.	15	9	11	11	10	7	10	11
Max.	44	34	32	41	38	32	38	44
Min.	-46	-15	-43	-43	-42	-41	-31	-46
Slope (%)								
Mean	68	30	48	49	42	29	41	47
Std. Dev.	25	17	22	22	24	16	22	24
Max.	232	141	104	232	242	169	242	242
Min.	0	0	0	0	0	0	0	0
Aspect (°)								
Mean Angle	39	146	164	170	228	310	65	187
Std. Ang. Dev.	57	69	50	78	76	68	72	81

Table 4—Descriptive statistics of exposure factors for each subalpine/alpine community type on the Katahdin Range, ME. The slope shape index is a relative scale where increasing positive values represent increasing convexity, increasing negative values represent increasing concavity, and a plane is represented by the value 0.

	Birch-alder	Cushion-tussock	Herbaceous snowbank	Krummholz	Cliff	Fellfield	Sedge meadow	Heath shrub-rush	All
Elevation (m)									
Mean	1108	1376	1307	1219	1277	1283	1484	1319	1240
Std. Dev.	116	58	155	113	159	156	78	147	146
Max.	1445	1575	1507	1551	1603	1603	1576	1603	1603
Min.	783	1195	950	859	834	859	1404	934	783
Slope Shape									
Mean	-6	18	-2	2	9	7	17	12	4
Std. Dev.	14	8	18	11	22	17	6	13	15
Max.	44	43	26	48	80	60	27	79	80
Min.	-53	3	-36	-50	-45	-49	2	-35	-53
Slope (%)									
Mean	60	26	70	48	113	58	11	36	54
Std. Dev.	33	26	24	36	78	33	2	30	42
Max.	947	174	216	969	1815	1462	21	810	1815
Min.	0	0	19	0	0	0	2	0	0
Aspect (°)									
Mean Angle	60	263	97	265	20	171	302	335	263
Std. Ang. Dev.	73	72	58	73	77	72	23	74	78

all alpine plant communities have a highly significant difference ($p<0.001$) compared to the distribution of all available habitat. Chi-squared goodness-of-fit tests indicate that the aspect distribution of all alpine plant communities have a highly significant difference ($p<0.001$) compared to the available aspect distribution. With the large number of degrees of freedom in our analysis, the statistical power to identify these differences is not unexpected.

One area of introduced error for the Presidential Range comes from 'streaking' in the available DEM. Since the data for all four of the exposure factor variables is derived from the DEM, this probably added substantial error to the data set. Another factor is the scale chosen for the exposure factors. For example, shape index derived from points 285 m away is unlikely to indicate any real variation in community type caused by microtopography within, say, a 10 m radius. Conversely, slope and aspect may have a stronger affect on community type at a scale larger than the 3 m radius used in our study.

Alpine-Treeline Ecotone Boundary

Designating a line between the subalpine krummholz and the forest is a somewhat arbitrary and subjective decision. For this study, the lower elevation limits of krummholz were defined as where vegetative growth is generally -2.5 m in height. The upper limits of continuous krummholz (the alpine-treeline ecotone or ATE boundary) can vary from a sharp boundary to a band of diminishing islands of krummholz. In other cases, it can be at an abrupt cliff or slide prone area. Therefore, the almost continuous band of subalpine krummholz extending around our study mountains is not all suitable for monitoring the alpine-treeline ecotone boundary. We developed a map where the ATE boundary can be readily identified and is suitable for future biomonitoring purposes. On the Presidential Range, the measurable ATE boundary ranged in elevation from 1,114 to 1,687 m (range = 573 m; x = 1513 + 93 m), while it varied from 857 m to 1518 m (range = 661 m; x = 1266 +116 m) on the Katahdin Range. The highest krummholz islands of map unit size, which are not necessarily the highest elevation of krummholz growth, are at 1,735 and 1,551 meters elevation, respectively, for the Presidential and Katahdin Ranges. Therefore, on different parts of the mountain, the upper limits of spruce-fir krummholz range from 621 to 694 m for these mountain ranges, respectively.

Biologists and climatologists have recognized that the limit of tree growth in both the alpine zone and the arctic in North America and Eurasia, north of the tropics, approximates the 10 °C isotherm for the warmest month of the year, usually July (Arno and Hammerly 1984). Temperature declines approximately 1-2 °C for every 300 m in elevation gain, due to the reduction in atmospheric pressure and expansion of the air. The wide elevation ranges we measured in the ATE and uppermost krummholz islands for both mountain ranges suggest that the concept of treeline and the upper limits of tree growth as a temperature-caused phenomena on the Northeast's highest peaks is far too simplistic. We hypothesize that tree growth on the northeastern US mountains is strongly influenced by the climatic growing season and exposure factors.

Although elevation is recognized as an important factor in determining the location of krummholz, models that incorporate topographic exposure with elevation more accurately predict treeline for the Presidential Range (Bryant and others 1991). The extent of treeline on the Presidential and

Katahdin Range reaches higher elevations in the valleys compared to the ridges. This corresponds to the exposure factors of wind and rime ice formation in the winter. We are now using our data to adapt the models developed by Bryant and others (1991) and Allen and Walsh (1996) as a benchmark for monitoring treeline movement, if any, over time.

Summary

Topographic features that influence cloud water (summer) and rime ice (winter) deposition due to wind-driven clouds and the deposition of snow blown off the exposed alpine area onto the leeward side of the mountain probably influence the alpine-treeline ecotone boundary and distribution of alpine plant communities. The highest elevation plant communities are the sedge meadow and cushion-tussock communities; the cushion-tussock is found in more convex topography subject to the greatest wind removal of snow while the sedge meadow tends toward a northwest aspect. Birch-alder, more appropriately a subalpine community, is strongly related to steep, concave slopes with an easterly vector—where the likelihood of blown snow accumulation and resulting avalanches is greatest. The herbaceous snowbank community tends toward concave relief with a more east to southeast vector, factors that also favor snow accumulation. The krummholz, fellfield and heath-shrub-rush communities tended to have less pronounced relationships with topographic features.

The alpine-treeline ecotone boundary and upper limits of the krummholz islands vary substantially by elevation, suggesting that growing season is not necessarily the dominant factor controlling the limits of tree growth on the Northeast's highest peaks. We postulate that the Northeastern montane alpine-treeline ecotone boundary is strongly influenced by exposure factors that relate to the mechanical damage caused by winter ice events and wind, than by the growing season alone. Climatic changes that influence cloud frequency, wind, precipitation and ice loading at the upper elevations should have a strong influence on the alpine-treeline ecotone boundary.

This study developed maps of the alpine-treeline ecotone boundary and alpine vegetation communities on two mountain ranges in the Northeast. Since Wilderness areas are included, they will provide for future opportunities to measure geographic shifts by vegetation communities to climatic change.

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References

Allen, T. R.; Walsh, S. J. 1996. Spatial and compositional pattern of alpine treeline, Glacier National Park, Montana. Photogrammetric Engineering&Remote Sensing 62(11): 1261-1268.

Arno, S. F.; Hammerly, R. P. 1984. Timberline: Mountain and arctic forest frontiers. Seattle, WA. The Mountaineers. pp. 26-30.

Batschelet, E. 1981. Circular statistics in biology. London, England. Academic Press. 371 pp.

Belcher, C. F. 1980. Logging railroads of the White Mountains. Boston, MA. Appalachian Mountain Club. 242 pp.

Bliss, L. C. 1963. Alpine plant communities of the Presidential Range, New Hampshire. Ecology 44: 678-697.

Bryant, E. S; Ricketts, T. H.; Birnie, R. W.; Kimball, K. D. 1991. Use of digital elevation data, Landsat TM, and vector map data to model treeline in the Northeastern U.S. Denver, CO. Presented at the Eighth Thematic Conference on Geologic Remote Sensing.

Clark, S. 1996. Katahdin , A Guide to Baxter Park and Katahdin. Unity, ME. North Country Press. pp. 1-88.

Cogbill, C. V.; Hudson, Jr., W. D. 1990. Final Report to the AMC Murphy Fund committee on "The baseline characterization of the alpine area of Katahdin."

Day, R. T.; Scott, P. J. 1984. The biology of Diapensia lapponica in Newfoundland. Canadian Field Naturalist. 98: 425-439.

Eastman, J. R. 1992. IDRISI: User's Guide and Technical Reference version 4.0. Clark University, Worcester, MA. 178 and 213 pp.

Flaccus, E. 1959. Revegetation of landslides in the White Mountains. Ecology. 40: 692-703.

Foster, J. R.; Reiners, W. A. 1983. Vegetation patterns in a virgin subalpine forest at Crawford Notch, White Mountains, New Hampshire. Bull. Torrey Bot. Club. 110: 141-153.

Gates, D. M. 1993. Climate change and its biological consequences. Sunderland, MA. Sinauer Assoc., Inc. 280 p.

Grabherr, G.; Gottfreid, M; Paul, H. 1994. Climate effects on mountain plants. Nature. 369: 448.

Gottfried, M.; Pauli, H.; Grabherr, G. 1998. Prediction of vegetation patterns at the limits of plant life: A new view of the alpine-nival ecotone. Arctic and Alpine Research. 30(3): 207-221.

Griggs, R. F. 1942. Indications to climate changes from the timberline of Mount Washington. Science. 95: 515-519.

Hudson, W.D.; Cannarella, R.; Garnett, L.; Huntington, K. 1985. Old-growth forest, subalpine forest, and alpine areas in Baxter State Park. Augusta, ME. Maine State Planning Office Misc. Report # 31. 88 pp.

Karlan, W. 1998. Climate variations and the enhanced greenhouse effect. Ambio 27 (4): 270-274.

Kimball, K. D.; Keifer, M. 1988. Climatic comparisons with tree-ring data from montane forests: are the climatic data appropriate? Can. J. For. Res. 18: 385-390.

Leak, W. B. 1975. Age distribution in virgin red spruce and northern hardwoods. Ecology. 56: 1451–1454.

Leak, W. B.; Graber, R. E. 1974. Forest vegetation related to elevation in the White Mountains of New Hampshire. Durham, NH: USDA Forest Service, Research Paper NE-299.

Marchand, P. J. 1987. North Woods: An Inside Look at the Nature of Forests in the Northeast. Boston, MA. Appalachian Mountain Club. 141 pp.

Myneni, R. B.; Keeling, C. D.;Tucker, C. J.; Asrar, G.;Nemani, R. R. 1997. Increased plant growth in the northern latitudes from 1981 to 1991. Nature. 386: 698

Randall, P. E. 1983. Mount Washington: A guide and short history. 2nd ed. Down East Books, Camden, ME. 170 pp.

Sperduto, D. D. 1994. A Classification of the Natural Communities of New Hampshire. New Hampshire Natural Heritage Inventory. Concord, NH. Department of Resource and Economic Development.

Spear, R. W. 1981. The history of high-elevation vegetation in the White Mountains of New Hampshire. Ph.D. Thesis, University of Minnesota. 215 pp.

SYSTAT. 1996. SYSTAT 6.0 for Windows: Statistics. Chicago, IL. SPSS. 751 pp.

Tiffney, W. N. 1972. Snow cover and the Diapensia lapponica habitat in the White Mountains, New Hampshire. Rhodora. 74: 358-377.

Worrall, J. J.; Harrington, T.C. 1988. Etiology of canopy gaps in spruce-fir forests at Crawford Notch, NH. Canadian Journal Forest Research. 18: 1463-1469.

Effects of the Suwannee River Sill on the Hydrology of the Okefenokee Swamp: Application of Research Results in the Environmental Assessment Process

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Abstract—The Okefenokee Swamp is a 200,000 ha palustrine, freshwater wetland in the southeastern United States managed as a National Wildlife Refuge and a National Wilderness Area. Wildfires frequently occur, modifying vegetation structure and creating the swamp landscape mosaic. Following extensive wildfires in 1954-1955, the Suwannee River was impounded by a dam (Suwannee River Sill) built outside the Wilderness Area but within the Refuge to exclude fire reoccurrence. By the late 1980s indications were that fire was not being excluded, although the swamp hydrology and vegetation suggested changes due to extended hydroperiod. The dam's effects were delineated with a spatial hydrology model and studies of species' hydrological sensitivities, and an Environmental Assessment considered the multiple uses and management goals to determine the best sill management alternative.

The Okefenokee Swamp is a 200,000 ha palustrine, freshwater wetland in southeast Georgia and northeast Florida. Two coastal plain rivers, the Suwannee and the St. Marys, originate within its landscape. The swamp was relatively undisturbed by explorers and settlers until the end of the 19th century, when it was subjected to draining, timber harvest and peat mining. Protection and preservation of the landscape and remaining resources were goals in 1937, when the swamp became part of the National Wildlife Refuge System. The Suwannee River sill, a low earthen dam constructed in 1960 across the main outflow channel of the Suwannee River where it exited the swamp, was also intended to protect and preserve the swamp. Built in response to fires that burned across the swamp and into the surrounding properties during 1954-1955, the sill was to impound water in the Okefenokee Swamp to keep similar fires from igniting and burning in the swamp. Further protection of the swamp was intended in 1974 when most of the Refuge (excluding the sill structure and adjacent area, and perimeter fire management compartments) was designated as a National Wilderness Area. During the 30 years following construction of the sill concern about the health of the swamp ecosystem began to emerge. Was the Suwannee River sill responsible for altering swamp vegetation, or were the perceived changes artifacts of the observers' temporal and spatial scales? Rather than "protecting" the swamp, was the sill damaging the wetland by disrupting the natural hydrologic environment and, subsequently, the vegetation community dynamics? During 1989, the sill structure was examined and found to be in need of extensive repair. Should the sill be repaired, modified or removed?

Addressing these questions required examination of the Okefenokee Swamp landscape composition and structure and the processes that create and maintain this structure. Hydrology is a primary driving function of all wetlands, and the hydrologic regime, principally hydroperiod (duration of flooding), determines wetland type (Mitsch and Gosselink 1986). Many wetlands are also shaped by fire, and fire suppression may compromise wetland integrity (Mitsch and Gosselink 1986). In these systems, fire and the hydrologic regime are intricately linked; periodic droughts create conditions favorable for burning. Fires occur, potentially altering site environments (soil composition, site elevation and hydrologic features) and subsequent species composition. Alterations of frequencies, intensities and extent of these processes (fire and the hydrologic regime) can modify landscape composition and structure (DeAngelis and White 1994). Human activity has disrupted Okefenokee Swamp hydrology and fire regimes. Hierarchy theory (Allen and Starr 1982; Allen and Wyleto 1983) suggests that the extent of these disruptions depends both on the organizational level of the ecosystem normally affected by these processes and the relative importance of the affected driving function (e.g., hydrology) in maintenance of the system hierarchy.

Upon completion of the study of the sill's effects on the swamp hydrology and vegetation composition and distribution, an Environmental Assessment (EA) of the sill's effects was formally implemented by the U.S. Fish and Wildlife Service and Okefenokee National Wildlife Refuge staff to aid in decision-making for sill management. In compliance with the provisions of the National Environmental Policy Act (NEPA), the EA was prepared to evaluate sill management alternatives and their environmental consequences. Determination of the need for an Environmental Impact Statement (EIS) could also be achieved in this process. This

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assessment also provided an opportunity to examine the appropriateness of the sill and its management in a designated Wilderness Area. The process provided opportunity for public education in workshops, press releases and public comment periods on the proposed management alternatives. A summary document and proposed plan of action concluded the EA.

Study Area Description

The Okefenokee Swamp is a complex of forested uplands and freshwater wetlands covering approximately 1670 km^2 of the lower Atlantic Coastal Plain in southeast Georgia and northeast Florida (fig. 1). Approximately 80% of the swamp is within the Okefenokee National Wildlife Refuge. Formation of the wetland landscape began at least 6,500 years ago, as plant decay was delayed by continuous flooding, which created anaerobic, acidic conditions favorable for peat production (Cohen 1973a). Peat accumulation continues today and is punctuated by periods of extreme drought, when peat is removed by fire and oxidation.

The swamp's watershed (3,702 km^2) includes three drainage basins (Rykiel 1977; Hyatt 1984; Brook and Hyatt 1985). The Suwannee River carries 85% of the exiting flow from the western swamp; the St. Marys River (11%) and Cypress and Sweetwater Creeks account for the remainder (4%) exiting the southern third of the swamp (Rykiel 1977). Groundwater exchange is minimal (Brook and Hyatt 1985; Hyatt and Brook 1984). Water enters the swamp as precipitation (70%) and surface drainage of uplands along the western and eastern boundaries (Rykiel 1977). Water levels are generally lowest during April-May, when evapotranspiration (ET) demands are high and seasonal precipitation is low, and October-November due to low precipitation (Loftin 1998). Most rainfall occurs during June-September.

Several vegetation communities occur in the Okefenokee Swamp. Shallow prairies of emergent and floating aquatic macrophytes are found where peat layers are thick over depressions in the basement topography (Cohen 1973a, 1973b, 1974; Cohen and others 1984) and cover approximately 8% of the swamp (Loftin 1998). Forested areas of pond cypress (*Taxodium acsendens*), loblolly bay (*Gordonia lasianthus*) and dahoon holly (*Ilex cassine*) cover 57% of the swamp (Loftin 1998). Slash pine (*Pinus elliottii*) and longleaf pine (*P. palustris*) occur on the remaining area of sandy islands and ridges (5%) (Loftin 1998). Dense shrub thickets fill the remaining swamp interior (29%) (Loftin 1998). Much of the western portion of the swamp, where mixed forests of pond cypress, loblolly bay and blackgum (*Nyssa sylvatica* v. *biflora*) historically predominated, was logged during 1900-1930 (Izlar 1984). This area currently supports stands of shrubs and hardwoods, with little cypress regeneration (Hamilton 1984, 1982; Loftin 1998).

The classic model of hydrarch succession (development of a terrestrial forest climax community from an open water body) directed by autogenic processes (Mitsch and Gosselink 1986) is only partially applicable to the swamp. The regional topography facilitates collection of surface water in the swamp, and periodic droughts expose the accumulated peat, allowing oxidation and decline in the surface elevation. Site

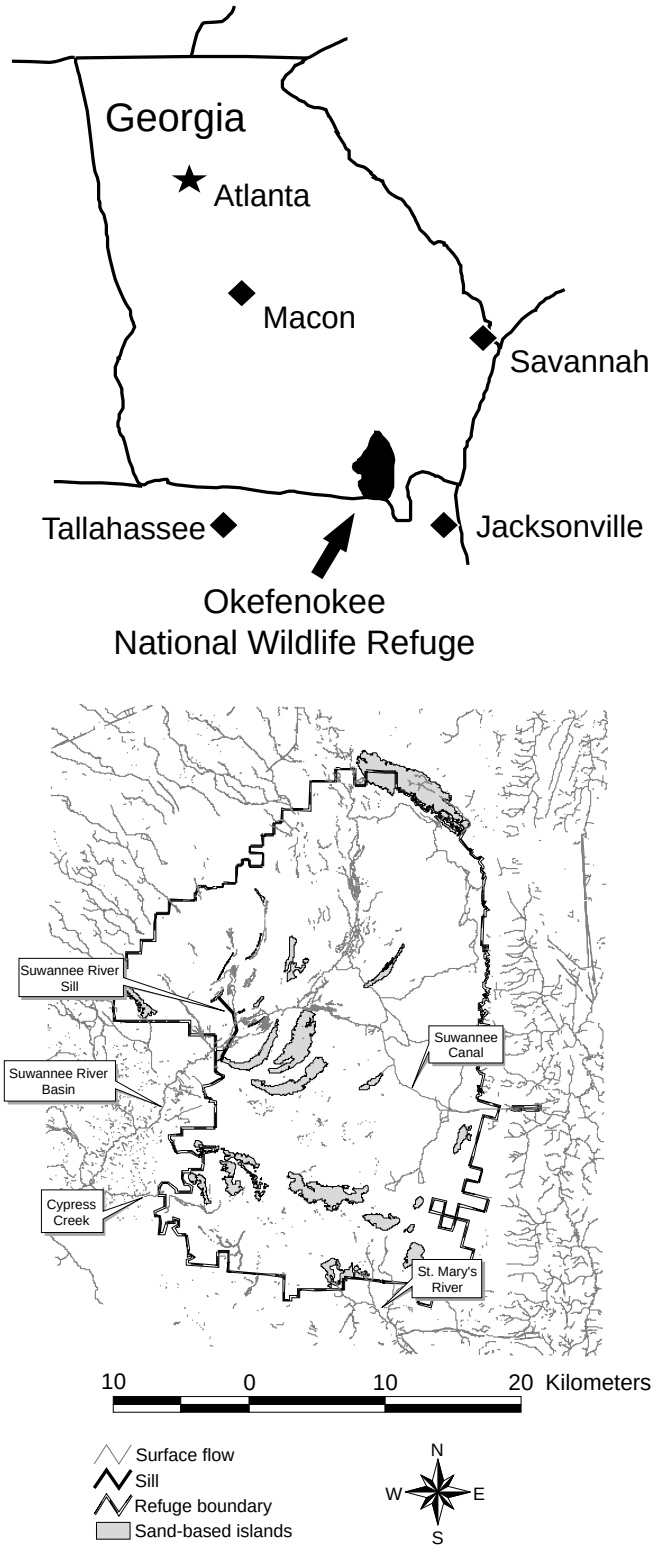


Figure 1—Location of the Okefenokee National Wildlife Refuge in Georgia.

elevations are raised as plant debris accumulates, creating more favorable conditions for species less tolerant of flooding. A progression from prairie to cypress swamp to broadleaved evergreen or mixed cypress swamp occurs in the absence of fire as peat accumulates (Hamilton 1982, 1984). However, in the swamp's history, this sequence has frequently been disrupted when drought, fire and subsequent species changes occur, and the wetland landscape mosaic is maintained (Hopkins 1947). Manipulations of the swamp vegetation composition (through logging) and hydrology (through trail, canal and sill construction and maintenance) during the past two centuries, as well as current fire management (suppression, control and prescribed burning), have affected fire frequency and occurrence across the swamp (Loftin 1998).

Purpose of the Suwannee River Sill

During 1954-1955, nearly 80% of the swamp was burned by wildfires during a severe drought (Hamilton 1982, 1984). Many of these fires began in the surrounding uplands, spread into the swamp where the peat slowly burned and returned to the perimeter uplands. Neighboring landowners sustained significant property loss from these fires. There was great interest in protecting the swamp and surrounding lands from future fires; a law was enacted by the United States Congress in 1956 to require construction of a dam, the Suwannee River sill,

> ...to protect the natural features and the very substantial public values represented in the Okefenokee National Wildlife Refuge, Georgia, from disastrous fires..., and for the purpose of safeguarding the forest resources on more than four hundred thousand acres of adjoining lands recently damaged by wildfires originating in or sustained by the desiccated peat deposits in the Okefenokee Swamp. (Chapter 742, Public Law 81-810, 70 Statute 668, pages 781-782).

A perimeter road that would permit access to remote areas for fire control and serve as a fire break to spreading fires was also required by the law. In 1962, construction of the sill berm and closure of the two spillway gates were completed. The berm spans 7.2 km and averages 35.5 m above mean sea level and 3-4 m above the surrounding Suwannee River floodplain; a ditch borders its entire length to the east. The berm does not intercept the entire river floodplain in the swamp; significant flow bypasses and exits west of the sill. The original south gate collapsed in 1979 and was replaced; the north gate is the original structure. Although the gates are maneuverable, they remain closed to maximize impoundment. The 1974 Wilderness Area designation excluded the sill and adjacent area from protection.

Prolonged flooding by impounding runoff and stream flow may reduce water level variation that normally occurs with precipitation (Finn and Rykiel 1979). Yin (1990) and Yin and Brook (1992) estimated an increase in average storage and a decrease in discharge throughout the swamp after sill construction. If the sill is extending periods of high water, it may be altering the landscape by affecting vegetation succession. Decreased fire frequency and extent may be encouraging woody vegetation to invade prairies during the occasional drier periods, hastening succession to cypress or bay swamp, and eliminating the mosaic of vegetation and the associated biodiversity in a landscape historically perpetuated by periodic disturbances (Hamilton 1982, 1984).

Problem Statement

Apparent changes in vegetation composition of the Okefenokee Swamp during 1960-1990 precipitated concern that the Suwannee River sill and the Okefenokee National Wildlife Refuge fire management policy were permanently altering the swamp's ecology (Roelle and Hamilton 1990). The Suwannee River sill was constructed to prevent recurrence of fires during periodic drawdowns. During 1962-1990, extensive fires did not occur in the swamp. However, this may have been the result of the Refuge's fire management policy rather than the impoundment effects of the sill. In fact, scattered fires during 1990 and 1993 suggest that the sill had not eliminated fire. Thus, the sill was performing as it was intended (to suppress fires) only in its localized area during periods of average hydrologic conditions; this temporally and spatially extended hydroperiod beyond the local area during intervening years when water levels were generally higher (Roelle and Hamilton 1990) but did not retain a substantial amount of water during extended periods of below average rainfall (Loftin 1998).

When the study of the processes that shape the swamp landscape was initiated in late 1991, the uncertainty of the sill's effects on the hydrology and vegetation of the swamp raised questions of whether it should be opened, repaired as a fixed height weir or replaced with a controllable structure. The swamp's Wilderness designation also had to be considered; although the sill was in place when this designation was made and the Wilderness-protected area excludes the sill structure, the extent of the sill's effects into the Wilderness Area was unknown. Effects of the sill on vegetation communities within the landscape needed to be documented and predicted effects of future hydrologic management alternatives analyzed so that the swamp hydrology could be appropriately managed to meet Refuge and Wilderness Area goals. To address these needs, it was necessary to analyze the swamp vegetation and shaping functions from several spatial and temporal scales. Hydrologic monitoring and topographic surveying at locations throughout and surrounding the swamp provided data for describing the swamp hydrology. Wildfire and prescribed burning records provided a spatial history of fire to compare with hydrologic and vegetation distribution information. Pre-logging surveys and post-logging aerial photography and satellite imagery classification indicated vegetation distributions resulting from natural successions, wildfire management and logging. A spatial hydrology model was developed and used to estimate the spatial extent of the sill's influence on the swamp hydrologic environment. A geographical information system (GIS) was used to identify the spatial relationships of these components to the sill and to current vegetation community distributions and hydrologic features, elucidating the sill's effects on the swamp ecosystem. The research findings addressed many of the issues raised in the subsequent EA process that was initiated after the research had concluded.

Methods

The Suwannee River Sill Environmental Assessment (EA)

The EA Process—Management of the Okefenokee National Wildlife Refuge is governed by the established purposes, as well as the recently passed National Wildlife Refuge System Improvement Act. In addition to these general guidelines, the U.S. Fish and Wildlife Service (FWS) was directed to construct the Suwannee River sill as a result of congressional action embodied in Public Law 84-810 (70 Stat. 668). The FWS is required to carry out this law unless otherwise instructed by Congress.

Deterioration of the Suwannee River sill and potential safety hazards identified periodically since 1982 made repairs necessary. In 1990, a workshop was held addressing the FWS's concern that the sill and the current fire management policy might be altering the floristic composition and wildlife use of the Okefenokee Swamp (Roelle and Hamilton 1990). Although the Suwannee River sill was constructed prior to the establishment of the National Environmental Policy Act (NEPA), the process of preparing environmental documents (such as EAs) to aid in decision-making and assist in informing and involving the public was recommended. This process was initiated in April 1997, when Georgia Representative Saxby Chambliss requested that an EA be conducted to assess future sill management (fig. 2). Immediate remedial action to the structure was recommended following an October 1997 report giving the sill an overall safety classification of "unsatisfactory".

An environmental assessment is prepared to evaluate alternatives and environmental consequences to determine if the environmental impacts are significant enough to warrant preparation of an Environmental Impact Statement (EIS). If the impacts are not significant enough for such a document, the proposed action can be implemented without further documentation. Although the EA process does not require an official scoping meeting, the FWS sponsored workshops at two locations near the Okefenokee Swamp to disseminate general information about the sill. Notices and articles announcing the workshop and introducing the issues were presented in the local newspapers. Comment packets were mailed to interested parties. Results from recently completed comprehensive investigations of the sill's effects on the swamp hydrology and associated landscape alterations (see discussion in next section) were presented at the workshops, giving the public a chance to learn about the subject and correct misunderstandings about the sill. Following the presentation, representatives from the Refuge and the Georgia Department of Natural Resources Fisheries Division listened to the public's concerns and answered questions. Public comments at these meetings were recorded, and written or verbal comments were accepted for 30 days following the workshops. All concerns raised during these workshops and in the comment packages, as well as applicable technical issues, were reviewed and used to develop management alternatives.

In the process of identifying the issues, alternatives and preferred alternatives, meetings and consultations were held with various state and federal agencies, adjacent landowners and civic and environmental organizations.

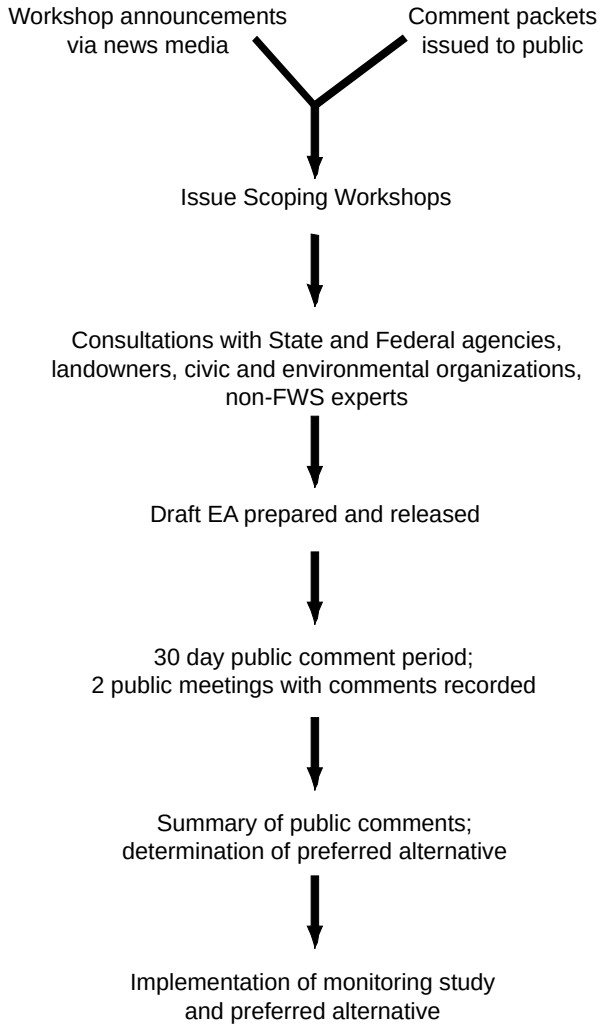


Figure 2—Approach of the Suwannee River sill Environmental Assessment

Okefenokee National Wildlife Refuge and Regional Office staff coordinated preparation of the EA, consulting non-FWS experts and information sources to ensure adequate coverage of each impact topic. After the draft EA was released, comments on the proposed action were gathered during a 30-day public comment period and two formal public meetings. A public outreach plan was also developed to address questions and concerns arising during the preferred alternative implementation.

Determination of the Preferred Alternative—The four alternatives addressed in the EA are outlined in table 1. Implementing regulations for NEPA provide for the elimination of some alternatives from detailed study, following a brief discussion of the reasons for doing so. After evaluation, a fifth alternative of expanding the sill structure and constructing additional structures within the Refuge was not considered a reasonable alternative and was not evaluated further. The environmental impacts of each alternative on hydrology, water quality, vegetation, fire, forestry, fisheries, wildlife, archeological and historical resources, public use and the local economy were addressed and

Table 1—Alternatives addressed in the Suwannee River sill environmental assessment.

Alternative	Action
A	No action (continue minimal maintenance/ monitoring)
B	Phased removal of concrete water control structures and breaching of the sill in selected locations (Preferred Action).
C	Remove Suwannee River sill and water control structures completely.
D	Repair and maintain the original structure.

evaluated in relation to the mission and goals of the Refuge. The preferred alternative was selected on the basis of reestablishing the natural processes within the swamp and restoring the link between the swamp and the Suwannee River. Public interest in the future recreational use of the area was considered, as well as public safety. A cost-benefit analysis was conducted in the final step.

Research Applied in the Ecological Assessment Process

An extensive analysis on effects of the Suwannee River sill on the Okefenokee Swamp landscape (Loftin 1998) preceded the EA. A brief review of these data is presented here.

Hydrology Studies—A spatial hydrology model (HYDRO-MODEL) was developed using ArcInfo and ARC GRID (version 7.3) to describe the swamp hydrologic environment, identify local- and system-level sensitivities to potential alterations in the Suwannee River sill structure, and compare type, location and extent of hydrologic and vegetation changes. Model development is detailed in Loftin (1998). The model was calibrated with weather and vegetation data representing conditions in the Okefenokee National Wildlife Refuge during 1980-1993 and topographic information collected during 1991-1994. The model is intended to represent the swamp hydrology cycling in twice-monthly time steps during 1980-1993. Independent data sets for 1941-1979 were used to assess model performance and system response to various manipulations. The "with-" and "pre-sill" conditions (1960-1993 and 1941-1959, respectively) were represented by topographic surfaces with and without the sill in place. The no-sill topographic surface was also modeled with hydrology data from 1980-1993 to demonstrate water surface elevations that might have occurred during that period had the sill been absent. Output data include water depth, water surface elevation and amount of water moved in each time step.

Wildfires in the Suwannee River Sill-Affected Area—Refuge records contain information primarily on wildfires that were suppressed and not on those that were naturally extinguished before detection. Therefore, it is not possible to determine if the sill affected total fire occurrence. However, it is possible to determine if the sill was elevating water levels during seasons of high fire frequency, if fires were arrested in the sill impact area due to elevated water levels, and if reported incidences of wildfires decreased following sill construction. These questions were addressed by comparing maps of wildfire ignition location and burn extent with a delineation of the sill-affected area and information on general hydrologic conditions at the time of the wildfires, summarized from the water level recorder database and model output surfaces. Comparisons were made using IMAGINE (version 8.2) summaries and overlays and ArcView map inquiries.

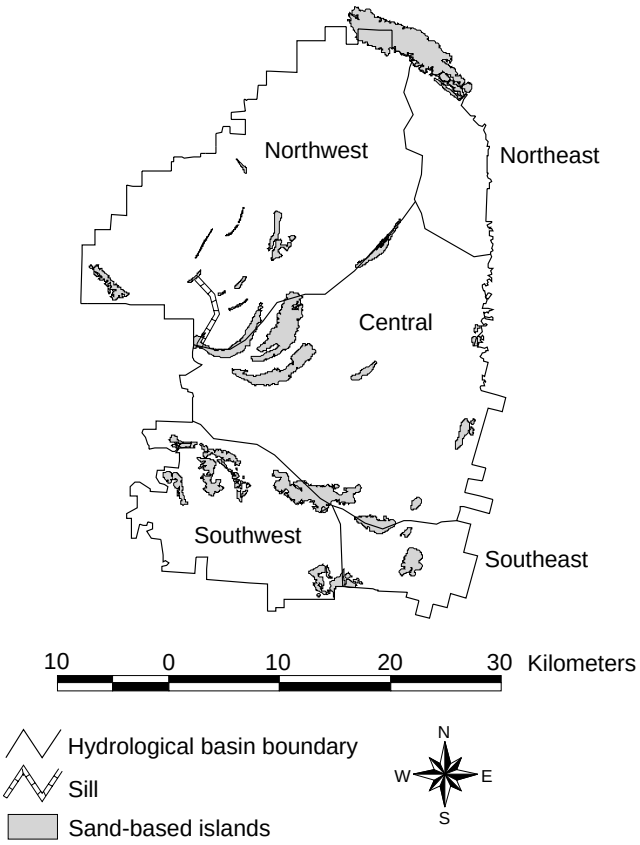
Vegetation Change in the Suwannee River Sill-Affected Area—Areas of vegetation change attributed to hydrologic modifications of the Suwannee River sill were determined with ERDAS-IMAGINE summary overlays of the estimated sill impact area and interpretations of pre-sill aerial photography and with-sill aerial photography and satellite imagery. Proportions of vegetation types inside and outside of the affected area were estimated and compared between the areas with these overlays. Comparisons of vegetation distributions relative to logging and wildfire histories are detailed in Loftin (1998).

Results and Discussion

The Sill's Effects on Swamp Hydrology

The complexity of the swamp hydrological environment was illustrated with swamp water level data and spatial hydrology model analysis. Water level data indicate that the Okefenokee Swamp contains sub-basins with similar seasonal trends but different water level variability and amplitudes (fig. 3). HYDRO-MODEL manipulations indicate that sensitivities to model parameters (ET, inflow volumes, outflow volumes) reflect differences in the hydrodynamics of these sub-basins (fig. 4). Although water depths did not change significantly in the northeastern basin with simulated sill removal, lower water depths were measured at stations in the western and southwestern basins. Responses in the Suwannee River floodplain in the western basin reflect the sill's absence from the topographic surface; however, responses in the southwestern creeks reflect the connectivity between the river and creek basins (particularly Sweetwater and Cypress Creeks) outside the Refuge boundary. Drainage of this region is affected by the topography of the river basin outside of the Refuge boundary. Peaks and troughs in the river channel slow drainage of the area, creating pooling in the Suwannee River above the topographic rise or berm, until water surface elevations exceed the crest, and overflow occurs. This condition is repeated throughout the Suwannee River floodplain in the Refuge interior, as well (fig. 5).

The central and southeastern basins behaved independently of the sill's presence in all but high water levels. Under low water level conditions, the Suwannee River floodplain drains rapidly as inflow is reduced, and water levels in the central and southeastern basins drop through evaporation. Under average conditions, flow in the central basin is limited to the western terminus of the Suwannee Canal. Under high water conditions, drainage from the central basin via the canal is delayed, as impoundment by the sill and the natural berms in the river floodplain delay de-watering.



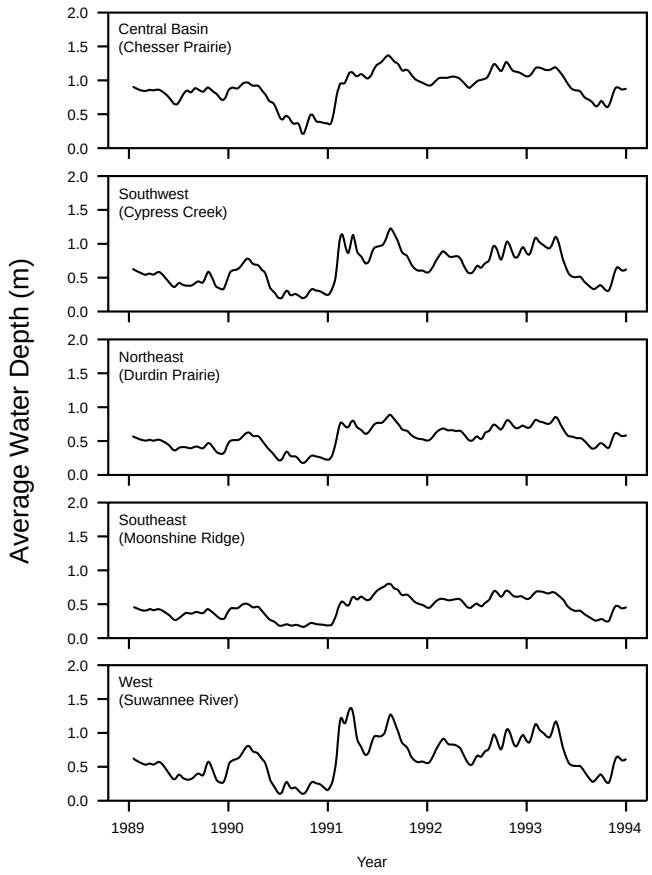


Figure 3—Hydrographs from Okefenokee Swamp sub-basins.

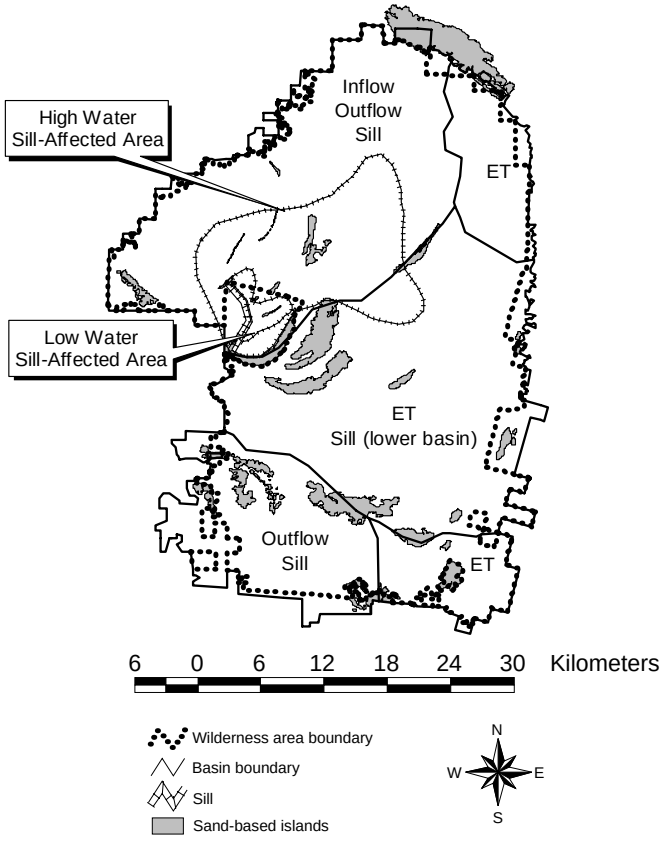


Figure 4—Regional differences in sensitivities to parameter manipulations in HYDRO-MODEL simulations.

Changes in water depths do not necessarily mean changes in inundation duration (hydroperiod). The significance of these hydrologic changes to swamp vegetation communities depends on species' sensitivities to the degree and timing of change (Loftin 1998). The western swamp experienced longer periods of slightly deeper water depths during 1960-1993 (with-sill) than during 1941-1959 (no-sill). Inundation depths and frequencies in the northeastern, central and southeastern swamp did not change during 1941-1993 with the addition of the sill during 1960-1993. Also, no changes in hydroperiod were indicated at northeastern, central and southeastern swamp when the sill was added to the 1941-1959 model runs or removed from the 1961-1993 iterations. Slightly lower water depths and shorter hydroperiods occurred in the western and southwestern swamp when the sill was removed from the 1960-1993 model iterations; longer flooding periods were recorded in these areas when the sill was added to the 1941-1959 simulations.

HYDRO-MODEL was also manipulated to increase the volume of water impounded by the sill. With this manipulation water depths in the area immediately surrounding the sill increased 1-1.5 m due to the reduced outflow; depths in the western swamp increased roughly 0.40 m, and no change occurred in the remainder of the swamp. Hydroperiods were also prolonged where the increased depths occurred.

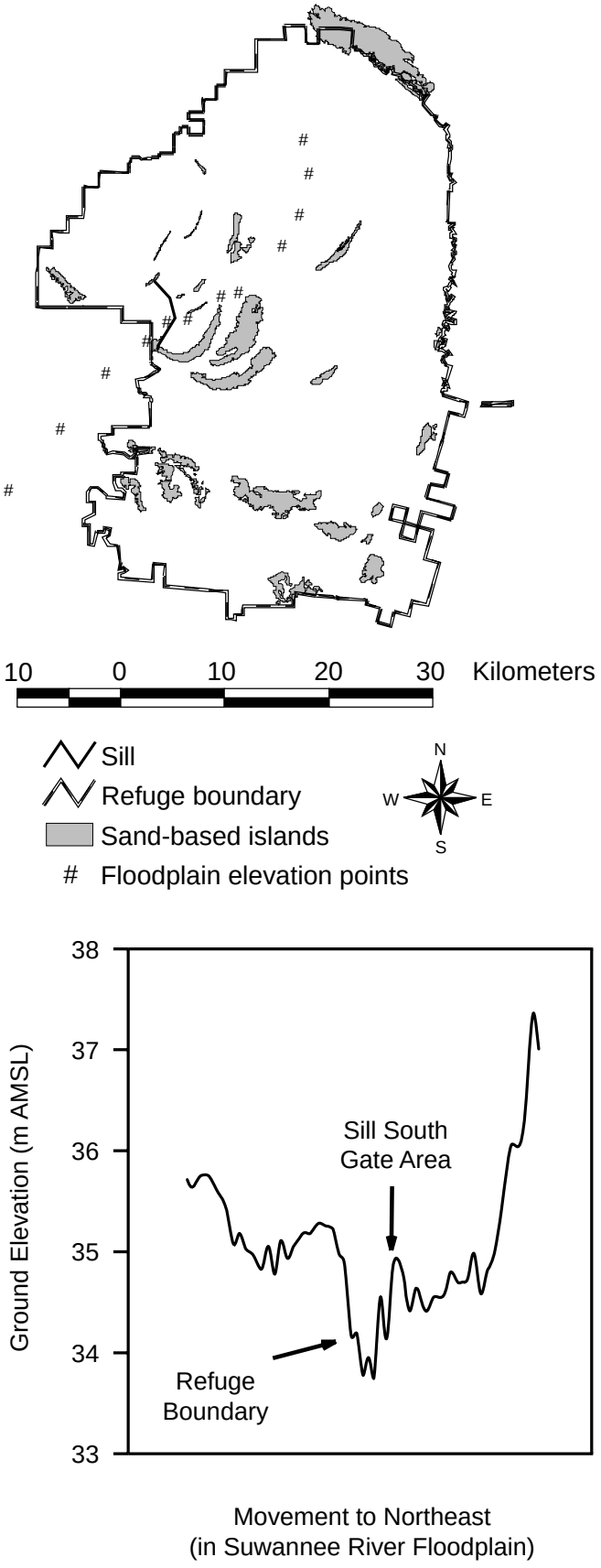


Figure 5—Elevation changes in the Suwannee River channel and floodplain in the Okefenokee National Wildlife Refuge and southwest of the Suwannee River sill.

Manipulations of evapotranspiration (ET) rates to examine potential effects of vegetation change on swamp water levels indicate that regional differences exist in the influence of this process on the swamp hydrology (fig. 4). Changes in ET volumes had significant effect throughout the swamp, particularly in basins outside the Suwannee River floodplain. Regional differences in vegetation distributions and topographic relief drive these responses. The higher topographic gradient in the river floodplain emphasizes changes in outflow volumes in the western swamp, whereas the prevalence of open water, aquatic and herbaceous prairie and the low topographic gradient are probably responsible for the importance of ET in the water budget in the remainder of the swamp.

The Sill's Effects on Wildfire Occurrence

More fires were reported in the Okefenokee Swamp during the with-sill period (151) than during the century prior (98) to its construction. Burned area decreased after sill construction, although this decrease was probably not due to the sill since water levels were low or at drought levels when most of the fires were ignited, and the fires occurred outside of the low-water and drought impoundment areas. The decrease was more likely due to fire suppression efforts and the absence of severe drought during 1960-1993 (Loftin 1998). Since 1855, 37 fires were reported in the area affected by the sill impoundment; 18 of these fires were prior to sill construction, and 11 were in the watersheds of the southwestern creeks (Loftin 1998). Most of the wildfires (25) in the sill-affected area ignited during June-October, when lightning strikes are most common and water levels rapidly decline in the absence of precipitation (Loftin 1998). Greatest impoundment usually occurs during winter months, when thunderstorms and lightning activity are infrequent, and water level accumulation occurs with reduced levels of evapotranspiration. The sill increases water levels during dry periods only in the immediate river floodplain of the southwestern swamp (fig. 4). Fire exclusion throughout the swamp will never be achieved with the present sill due to the limited affected area (18% of the swamp at high water levels) and seasonality of impoundment. Because the swamp hydrologic system is so tightly linked with area rainfall and evapotranspiration, the sill cannot impound enough water during the period when its impoundment effects are most needed to counteract drought and arrest wildfire spread.

The Sill's Effects on Swamp Vegetation

Types of vegetation changes occurring in the sill impoundment area mirror those in the remainder of the swamp, although change rates differ (Loftin 1998). Wet forest initially increased in the river floodplain affected area during 1952-1977 and was persistent during the next 13 years, whereas shrub, prairie and upland pine coverages were nearly halved during 1952-1990 (Loftin 1998). These changes occurred at rates slower than the surrounding swamp during 1952-1977 and then greater than the surrounding swamp during 1977-1990 (Loftin 1998). Shrubs flooded during the initial impoundment did not survive unless located on elevated surfaces. The apparent increase in proportion of

forested area was probably due to this relative decline in shrub coverage. Recruitment of trees and shrubs has been eliminated during the extended flooding; only periods of drought provide exposed surfaces for germination, and survival of seedlings is jeopardized by re-flooding before they achieve sufficient stature to survive impoundment. As in the remainder of the swamp, vegetation in the impounded area is succeeding in the absence of severe fire (Loftin 1998).

Applying Results from Scientific Research in the Environmental Assessment Process

HYDRO-MODEL simulations included manipulations of the sill and hydrological environment, and analysis of swamp hydrological sensitivity. Model predictions indicated the extent and intensity of hydrological changes expected with sill modification. Observed changes in vegetation distributions and wildfire occurrences and distributions were compared with HYDRO-MODEL predictions to establish relationships. This information was used extensively throughout the EA process. Questions arising during the scientific review and public comment period were addressed by referencing the research findings. This information contributed to the selection of the preferred alternative.

The hydrology study was concentrated within the Refuge perimeter. Information about the Suwannee River hydrology outside of the Refuge boundary was lacking. The FWS had an opportunity to proceed in a phased (defined in the preferred alternative) removal of the water control structures and earthen dike. Incorporated into the preferred alternative was a proposal to collect two years of baseline data downstream from the sill and verify HYDRO-MODEL predictions of downstream changes. Two years of monitoring with the water control structures opened will follow. A supplemental report summarizing the monitoring will be attached to the original EA upon conclusion of the supplemental study. Barring any documented negative impacts to public use or private landowners that cannot be mitigated through additional management actions or accepted as factors in the system restoration, the alternative will be fully implemented. This phased approach to preferred alternative implementation was also taken to address concerns of flooding due to above-average rainfall along the Suwannee River; the FWS formed a partnership with the US Geological Survey-Water Resources Division to monitor Suwannee River water levels and examine those concerns.

Comments on the draft EA illustrated the public's comprehension of the issues. Only seven individuals made verbal comments at the two public meetings. Eighty-five individuals responded in 67 written comments, and one person provided verbal comments by phone during the 30-day comment period. Eighty-five supported the preferred alternative, three supported Alternative C, and five supported Alternative D. Providing current, credible information to the public, agencies, and special interest organizations guided the EA process. This was an issue originally expected to be highly controversial, yet the use of recent technology and expanded analysis capabilities to study alterations in this large landscape guided the NEPA process to successful conclusion.

Conclusions

The Suwannee River sill was constructed to protect the swamp from drought and wildfires, processes once considered damaging to the swamp landscape. In the years immediately following sill construction, rainfall maintained swamp water levels and wildfires were infrequent. Wilderness designation occurred during this period of high water levels and low fire occurrence. Although the sill and its immediate surroundings were not included in the Wilderness Area protection, impounded areas further from the sill were in the designated Wilderness Area. By the early 1980s drought and wildfires were again occurring throughout the swamp, and the role of the sill in vegetation and hydrological changes was questioned. Research suggested that cycles of drought and fire were necessary to maintain the swamp landscape mosaic. The palustrine environment of the sill impoundment was in contrast to the naturally dynamic riparian hydrology existing prior to sill construction. Although limited in extent, the static hydrology created by the sill during years of normal rainfall was leading to changes in vegetation community composition and distributions.

Providing habitat for wildlife, arresting wildfire movement into surrounding privately-owned land, and ensuring access to the swamp for recreational users are issues directing management of the Okefenokee National Wildlife Refuge. Protecting the Okefenokee Swamp's naturalness, which is a goal in the designated Wilderness Area, requires recognition of the complexity of the driving processes that have shaped this landscape at multiple spatial and temporal scales. Humans have locally manipulated the swamp landscape with logging, peat dredging, trail maintenance, fire management, and the sill. The regional hydrological cycle, however, also shapes the swamp landscape. Droughts create conditions for landscape-altering fires to occur at decades to century intervals. These drought-fire cycles have occurred since swamp formation began thousands of years ago, and the effects are somewhat predictable. However, human-caused changes in the swamp landscape during the past century have affected this predictability by altering plant species compositions and peat and fuel accumulation rates. Coupled with these changes is the need for swamp management to achieve multiple goals, including producing and protecting of wildlife habitat, providing public recreation opportunities, and ensuring wilderness protection. The EA process presented a framework to recognize the various roles of the sill in this area managed with different objectives, as a National Wildlife Refuge and a National Wilderness Area. Results from scientific study of the sill's effects guided formulation of the management alternatives while recognizing the area's many uses, and public participation in the EA process provided an opportunity to build consensus necessary between refuge managers and the interested public for successful implementation of the preferred alternative.

Acknowledgments

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References

Allen, T. F. H.; Starr, T. 1982. Hierarchy: perspectives for ecological complexity. Chicago, IL: University of Chicago Press. 261 p.

Allen, T. F. H.; Wyleto, E. P. 1983. A hierarchical model for the complexity of plant communities. Journal of Theoretical Biology. 101:529-540.

Brook, G. A.; Hyatt, R. A. 1985. A hydrological budget for the Okefenokee Swamp watershed, 1981-82. Physical Geography. 5(2):127-141.

Cohen, A. D. 1973a. Possible influences of subpeat topography and sediment type upon the development of the Okefenokee Swamp-marsh complex of Georgia. Southeastern Geology. 15:141-151.

Cohen, A. D. 1973b. Petrology of some holocene peat sediments from the Okefenokee Swamp-marsh complex of southern Georgia. Bulletin of the Ecological Society of America. 84:3867-3878.

Cohen, A.D. 1974. Petrography and Paleoecology of Holocene Peats from the Okefenokee Swamp-Marsh Complex of Georgia. Journal of Sedimentary Petrology 44(3):716-726.

Cohen, A. D.; Andrejko, M. J.; Spackman, W.; Corvinus, D. 1984. Peat deposits in the Okefenokee Swamp. In: Cohen, A. J.; Casagrande, D. J.; Andrejko, M. J.; Best, G. R., eds. The Okefenokee Swamp: its natural history, geology, and geochemistry. Los Alamos, NM: Wetlands Surveys: 493-553.

DeAngelis, D. L.; White, P. S. 1994. Ecosystems as products of spatially and temporally varying driving forces, ecological processes, and landscapes: a theoretical perspective. In: Davis, S. M.; Ogden, J. C., eds. Everglades: the ecosystem and its restoration. Delray Beach, FL: St. Lucie Press: 9-27.

Finn, J. T.; Rykiel, Jr., E. J. 1979. Effect of the Suwannee River sill on Okefenokee Swamp water level. Water Resources Research. 15(2):313-320.

Hamilton, D. B. 1982. Plant succession and the influence of disturbance in the Okefenokee Swamp, Georgia. Ph.D. Dissertation. Athens, GA: University of Georgia: 254 p.

Hamilton, D. B. 1984. Succession and the influence of disturbance in Okefenokee Swamp. In: Cohen, A. J.; Casagrande, D. J.; Andrejko, M. J.; Best, G. R., eds. The Okefenokee Swamp: its natural history, geology, and geochemistry. Los Alamos, NM: Wetlands Surveys: 86-111.

Hopkins, J. M. 1947. Forty-five years with the Okefenokee Swamp. Bulletin of the Georgia Society of Naturalists. (4):1-69.

Hyatt, R. A. 1984. Hydrology and geochemistry of the Okefenokee Swamp. Ph.D. Dissertation. Athens, GA: University Georgia: 361 p.

Hyatt, R. A.; Brook, G. A. 1984. Ground water flow in the Okefenokee Swamp and Hydrologic and nutrient budgets for the period August, 1981 through July, 1982. In: Cohen, A. J.; Casagrande, D. J.; Andrejko, M. J.; Best, G. R., eds. The Okefenokee Swamp: its natural history, geology, and geochemistry. Los Alamos, NM: Wetlands Surveys: 229-245.

Izlar, R. L. 1984. A history of Okefenokee logging operations: a bourbon and branch water success story. In: Cohen, A. J.; Casagrande, D. J.; Andrejko, M. J.; Best, G. R., eds. The Okefenokee Swamp: its natural history, geology, and geochemistry. Los Alamos, NM: Wetlands Surveys: 5-17.

Loftin, C. S. 1998. Assessing patterns and processes of landscape change in Okefenokee Swamp, Georgia. Ph.D. Dissertation. Gainesville, FL : University of Florida: 864 p.

Mitsch, W. J.; Gosselink, J. G. 1986. Wetlands. New York, NY: Van Nostrand Reinhold. 539 p.

Roelle, J. E.; Hamilton, D. B. 1990. Suwannee River sill and fire management alternatives at the Okefenokee National Wildlife Refuge. Fort Collins, CO: U.S. Fish and Wildlife Service, National Ecology Research Center. 39 p.

Rykiel, E. J. 1977. The Okefenokee Swamp watershed: water balance and nutrient budgets. Ph.D. Dissertation. Athens, GA: University of Georgia: 246 p.

Yin, Z. 1990. The impact of the Suwannee River sill on the surface hydrology of Okefenokee Swamp. Ph.D. Dissertation. Athens, GA: University of Georgia: 352 p.

Yin, Z.; Brook, G. A. 1992. The impact of the Suwannee River sill on the surface hydrology of Okefenokee Swamp, USA. Journal of Hydrology. 136:193-217.

A Multiscale Method for Assessing Vegetation Baseline of Environmental Impact Assessment (EIA) in Protected Areas of Chile

Aníbal Pauchard
Eduardo Ugarte
Jaime Millán

Abstract—The exponential growth of recreation and tourism or ecotourism activities is affecting ecological processes in protected areas of Chile. In order to protect protected areas integrity, all projects inside their boundaries must pass through the Environmental Impact Assessment (EIA). The purpose of this research was to design a multiscale method to assess vegetation for the EIA baseline in protected areas of Chile and developing countries. The data obtained could be used to indicate patterns of biodiversity of the ecosystem at different scales, and at the same time monitor changes due to human activity. The method was applied in Conguillío National Park, in South Central Chile. Three scales of vegetation characterization were used. They are complementary and can be modified depending on the sensitivity of the ecosystem, the intensity of impacts and the human resources and technology available. Our method proved to be efficient in characterizing ecosystem diversity at different scales. We encourage the use of this multiscale method to assess vegetation baseline in protected areas.

The increasing world use of protected areas (PAs) for ecotourism (Ceballos-Lascurain 1996) can damage natural resource quality (Rivas 1994) and jeopardize the main role of protected areas in conserving biodiversity. This global trend is affecting the National Protected Areas System of Chile (SNASPE).

SNASPE covers 18.3% of the Chilean territory. Compared to an average of 8.2% of protected area worldwide (McNeely and others 1994), this percentage seems to be sufficient to achieve conservation goals, even though most of the Chilean protected areas are located in the climatic extremes of the country. Many important and diverse ecosystems in central Chile are scarcely represented or not at all in the system (Armesto and others 1992; Lara and others 1995; Villarroel 1992). SNASPE has four major environmental problems: 1) lack of representation of important ecosystems, 2) mining and extractive activities inside the PAs, 3) cross-boundary impacts like fragmentation, exotic weed invasions and pollution and 4) impacts produced by development and use of new infrastructure inside PAs.

Since 1996, the Chilean Forest Service has promoted a new system of tourism development in PAs (Lazo 1996). Now, private companies can apply for permits to develop tourist facilities and infrastructure inside PAs. Recreation development is necessary to satisfy the demand of the increasing number of tourist visitors to SNASPE.

Chilean environmental law demands that all projects in protected areas pass through an Environmental Impact Assessment procedure (EIA). The idea is to recognize, monitor and mitigate the impacts of development inside PAs. One of the key stages in the procedure is to develop a baseline or a description and study of initial conditions in the influenced area (Greene 1984; Stork and Samways 1995). The EIA baseline must describe and analyze biotic, abiotic and social components of the impacted system. Assessment, monitoring and mitigation of the impacts require accurate and useful baseline data (Conesa 1995).

Ecologists have used vegetation as an indicator of soil and climatic conditions for a long time (Grossman and others 1998). Recently, many authors have shown the potential of vegetation to indicate biodiversity of entire ecosystem (Krebs 1994). Vegetation controls most of the environmental conditions in ecosystems, including the energy and material flows. Furthermore, vegetation is the result of other animal-plant ecological interactions like herbivory, seed predation and frugivory. Vegetation characterization has proven to be one of the easiest ways to assess and classify the whole ecosystem. Vegetation is preferred because it can integrate a broader range of ecological processes in a site or landscape if some specific measuring criteria are used (Mueller-Dombois and Ellenberg 1974; Grossman and others 1998). At the same time, more information is available about vegetation than any other biotic component; probably because vegetation analysis demands less time and resources than the study of any other biotic component, but also because there has been a historically bias in focusing on vegetation for assessing natural systems.

In developing countries like Chile, there are not enough resources to assess all variables in biotic components for an EIA baseline, so some easily measured biodiversity indicator must be found (Stork and Samways 1995). With a multiscale approach, vegetation can be used to improve the characterization of ecosystem diversity. Scale-dependant patterns and processes in vegetation can be captured, and their interactions can be analyzed and understood. The

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correlation between temporal and spatial scale in ecological processes (O'Neill and King 1998) can be used, in this multiscale approach, to assess ecosystem function.

Objectives

In this study, we propose a multiscale method to use vegetation as an indicator for the biotic component of the EIA baseline for PAs. We define three levels for this approach, depending on the scale and the detail required for different development projects and the environmental characteristics of the affected area. Second, we apply the method to Conguillío National Park. The application tries to probe the advantages of our method compared to traditional one scale or plot based vegetation assessment methods.

The Method

We developed a multiscale method to analyze vegetation for the EIA baseline, using three stages. The stages correspond to successive approaches to vegetation from a broad to a fine scale. The cost of the successive stages increases with the detail required. The method for assessing an EIA vegetation baseline in PAs considers the three following stages: physiognomy, stand structure and composition. In this paper, we present a general description of each stage and the results of the application to our study area. We used Fosberg (1967) as a conceptualization to define the three stages.

Physiognomy

The vegetation physiognomy is defined by its overall physical appearance (Fosberg 1967). It combines structural features (height and spacing), growth form (morphology and aspect) and leaf attributes (seasonality and phenology) of dominant species (Grossman and others 1998). Even when physiognomy is the result of structure and composition of the vegetation, it is not necessary to directly measure these characteristics to identify vegetation physiognomy (Shimwell 1972). The spatial representation of plant communities is one key stage for assessing environmental impacts of development projects. The physiognomic categories for classification are broad (for example: forest, shrubland and grassland) and easy to assess even by non-specialists. We proposed using wide physiognomic categories to characterize and classify patches at landscape level. For this purpose, remote sensing technology must be used. Physiognomic types can be used to determine landscape structure (patches, matrix and landscape elements), to assess landscape diversity (Forman 1995) and to provide information about the impacts of the project in landscape elements. Spatial statistical models can be use to interpret the impacts on landscape (Turner and Gardner 1991).

We defined two steps for assessing physiognomic characteristics of vegetation:

1. Physiognomic types identification and characterization. This step integrates physiognomic and structural attributes for describing vegetation types after aerial photointerpretation. We proposed using the International category described by Fosberg (1967) and cited in Mueller-Dombois and Ellenberg (1974). Field recognition and confirmation of information collected with aerial photointerpretation are necessary to validate the results.

2. Vegetation mapping using physiognomic types. Physiognomic types should be represented in vegetation maps. Spatial distribution of the types, cover (absolute and relative) and possible impacted areas are easy to assess with vegetation maps. Geographic Information Systems (GIS) facilitate the management of data and the incorporation of more spatial variables. The spatial display of the information is crucial for management decisions. This is especially when a protected area still lacks a vegetation map, or the existing maps are in too broad scale to assess human impacts.

Stand Structure

Structure is defined as the spatial arrangement of the vegetation biomass (Fosberg 1967). Three elements define structure: 1) vertical structure, 2) horizontal structure and 3) abundance (Shimwell 1972). Therefore, any method to assess vegetation structure in the stand scale must consider these three variables in order to address the structural patterns of plant communities at the stand scale. We propose the two following basic steps for sample stand structural variables for EIA baseline in PA.

1. Random stratified sampling of structural attributes. In order to measure quantitative structural attributes like basal area, height, coarse woody debris, etc., we propose random permanent plot sampling, using physiognomic types as strata. Permanent plots will be useful for monitoring of the impacts after the execution of the project. This procedure includes structural profiles in horizontal and vertical dimension, using the same randomized points.

2. Regeneration assessment. Regeneration of dominant species must be addressed, using smaller plots inside the permanent plots. Seedling abundance and size distribution are useful indicators of stand dynamics.

Composition

Composition is the list of plant species that form vegetation (Fosberg 1967). Floristic classifications use species or groups of species to define vegetation types (Grossman and others 1998). Composition is crucial to determine plant diversity through the assessment of plant species richness and evenness. Functional attributes of vegetation, as life forms or deciduousness, can also be inferred using composition analysis.

We propose the following steps for assessing composition:

1. Floristic Relevés. The Braun-Blanquet method for classifying vegetation, using plant composition, has been shown to be consistent, easy to use and effective in describing plant communities and plant diversity. An adequate number of relevés must be sampled in order to cover plant community heterogeneity. Relevé plot size must be determined by species-area curves, depending on the vegetation type. This simple procedure optimizes the species richness assessment compared with standard size plot. Vegetation heterogeneity must be captured by stratifying the sample area, using physiognomic types or structural attributes. Vegetation in ecotones and riparian habitats, usually biodiversity hot-spots,

should be sampled with higher intensity to capture overall species diversity. Soil and disturbance features should also be recorded to understand general patterns of environmental gradients.

2. Community Classification. We propose the use of tabular comparison classification, using character species (Mueller-Dombois and Ellenberg, 1974). Multivariate pattern analysis could be used to confirm or to improve tabular classification. Communities should be named either inside or outside the phytosociological hierarchical system, depending on the information available for the study area. The use of phytosociological nomenclature allows ecosystem comparisons in a regional scale.

3. Floristic List. The floristic list should consider all vascular plant species found in relevés. Plants collected outside relevés must be included. Using both methods of plant collection, we ensure sampling of rare species or species with patchy. The species should be classified as native or exotic. Taxic diversity (Bisby 1995), expressed in families, genus and species number, should be calculated to assess biogeographical factors of plant diversity.

Case Study

In 1995, CONAF licensed the development of the Conguillío National Park recreation area. The project included the construction and management of 12 cabins and a restaurant. Old buildings and 100 campgrounds were already located in the area.

The area of study (38°38'S - 71°39'O), defined by direct impacts of the project, consists of 241 ha, where altitude ranges between 1,000 and 1,100 m. Climate is cool-moist-temperate with dry summer months. The average annual precipitation is around 2,000 mm. Forests and shrublands cover most of the area. *Araucaria araucana* (Monkey puzzle tree) and *Nothofagus* spp. (Southern beeches) dominate vegetation (Donoso 1993 and Gajardo 1994). Soils in this area have predominantly formed from recently deposited volcanic ejecta. Soil heterogeneity is greatly due to differences in the nature of the parental material (ashes, pumice, and lava) and time since its deposition (Casertano 1963; Peralta 1975; Pauchard 1998). Llaima Volcano activity and Conguillío Lake floods are the major natural disturbances affecting the area.

Results

Physiognomy

We found eight physiognomic types: four forests, three shrublands and one grassland. Physiognomic attributes in comparison with floristic attributes are shown in Table 1. Due to the small area affected by the project, we did not apply landscape analysis to the case study.

Stand Structure

Using stand structure attributes, we identified different successional stages related to the physiognomic types. Forests and shublands present an uneven aged structure. In older forests, *Nothofagus* spp. show an even aged stand structure, while *A. araucana* shows cycled recruitment. Heterogeneity within the stands is due to gap dynamics that create a fine mosaic of dominant tree cohorts. *Nothofagus dombeyi* (Coihue) forms old-growth forests with heights between 30-35 m and DBH around 80 cm, sharing the dominant story with *A. araucana* with DBH of 50 cm. On the other hand, *Nothofagus antarctica* (Nirre) only forms shrubland or short forest where *A. araucana* is the emergent story. In the understory, *Chusquea coleu* (Fam. Bambuceae) creates dense patches inside forests of *Nothofagus* spp. Most of the forest and shrubland has one sub-shrub story of *Pernettya* spp. (Fam. Ericaceae). Tree regeneration occurs in gaps where microclimate conditions are adequate for seedling growth. *A. araucana* seedlings prefer areas with herb or sub-shrub cover. *Nothofagus* spp. seedlings occupy bared areas with exposed mineral soil or coarse woody debris in advanced decay.

Composition

We classified 67 relevés in six plant communities, using tabular comparison. Four plant communities were forest, one shrubland and one grassland (Table 1). *N. dombeyi* communities are part of the subasociation Gaulherio Nothofagetum dombeyi araucarietosum Finck 1995 (Finckh 1996). *N. antarctica* communities belong to the sub-alianze Ribesi-Nothofagenion Eskuche 1969 (Eskuche 1973). The cluster analysis of the relevés by Euclidean distance showed similar patterns of clustering as the tabular comparison. This output helped to validate our tabular comparison results. We found 115 vascular plant species, of which 87 (83%) were natives and 18 (16%) exotic. The 115 species belong to 67 genera and 45 families. *A. araucana* is the only species within a conservation category (Benoit 1989).

Discussion

The advantage of our method is that it combines three different scale approaches to capture the whole diversity of plant communities. Most vegetation studies focus on only one of these criteria. In the last decade, literature has shown the importance of assessing ecological phenomena in different scales (Peterson and Parker 1998). Ecological processes are scale dependent, so a broader range of processes will be assessed if you look at different scales. In order to probe our method's advantages, we will analyze the case study results, discussing the implications for diversity assessment.

Physiognomy

Physiognomic classification allows us to display and to analyze vegetation types spatial patterns. Mapping and GIS management of the data give us a notion for assessing possible impacts of the project on vegetation. In the study case, the process of physiognomic classification clarifies the idea that we are dealing with complex vegetation mosaics where forest, shrubland and grassland are occupying different sites related more with soil and geomorphological attributes than with climatic gradients. Future research could check the effectiveness of physiognomic classifications at a landscape scale for assessing vegetation patterns

Table 1—Comparison between physiognomic and floristic classifications of vegetation. Physiognomic type, stratum, height, and area are attributes of structural sampling. Floristic plant communities, total number of species, average number of species per relevé and number of relevés sampled are attributes of composition stage. The stratum are: A: arboreus, I: Intermediate, ar: shrubs, h: forbs.

Physiognomic type	Dominant species	Height (m)	Stratum	Area (ha)	Floristic plant community	Total number of species	Average No. of spp. per relevé (range)	Number of relevés sampled
Tall closed evergreen forest	*Nothofagus dombeyi* - *Araucaria araucana*	35	A,I,ar,h	54,4	*Nothofagus dombeyi* - *Adenocaulon chilensis*	28	12 (9-15)	8
Medium tall closed evergreen forest	*N. dombeyi*	25	A,I,h	5,4	*Nothofagus dombeyi* - *Osmorrhiza chilensis*	8	5,3 (3-8)	3
Tall open evergreen forest	*A. araucana* - *Pernettya* spp.	30	A,ar,h	18,6	*Nothofagus antarctica* - *Pernettya pumila*	22	7,7 (4-12)	13*
Short closed deciduous forest	*Nothofagus antarctica* - *Pernettya myrtilloid*	13	A,I, h	16,5	*Nothofagus antarctica* - *Chusquea coleu* *Nothofagus antarctica* - *Embothrium coccineum*	36 31	8,9 (6-13) 12 (7-18)	21 8
Tall closed deciduous shrubland	*N. antarctica* - *A. araucana*	10	A,ar,h	17,8	*Nothofagus antarctica* - *Pernettya pumila*	22	7,7 (4-12)	13*
Tall open deciduous shrubland	*N. antarctica* - *A. araucana*	20	A,ar,h	71,0	*Nothofagus antarctica* - *Pernettya pumila*	22	7,7 (4-12)	13*
Short evergreen shrubland	*Berberis buxifolia* - *Ribes cucullatum*	1	ar,h	5,7	*Berberis buxifolia* - *Acaena pinnatifida*	28	9,7 (8-15)	10
Grassland	*Solidago chilensis* - *Phacelia secunda*	0,3	h	2,2	*Solidago chilensis* - *Phacelia secunda*	5	3,2 (5-1)	4
Volcanic ashes				13,8				
Lake border				35,0				
Total				240,7				

*Total number of relevés are in the three physignomic types.

and human impacts in PAs. For this purpose, the National Inventory of Native Vegetation of Chile would be an interesting example of state of the art in vegetation classification and PAs of developing countries.

Stand Structure

In the case study, the structural stage allows us not only to make predictions about vegetation dynamics, but also about wildlife habitat characteristics. Using stand structure, we can identify the relationship between physiognomic types and successional phase or disturbance regimes. In the study case, structural patterns of forests and shublands confirm Veblen (1982) and Veblen and others (1995) hypothesis of *A. araucana* - *Nothofagus* spp. dynamics. *A. araucana* seems to become dominant in absence of huge disturbance like lava. *A. araucana* uses the periods after low-intensity disturbances to grow. In these periods, *Nothofagus* spp. dies, liberating limited resources, especially light. Then *Nothofagus* spp. will establish again and due to their higher growth rate, they soon get into the upper canopy competing successfully for light and suppressing *A. araucana* growth. Structural complexity gets higher in old-growth forest of *N. dombeyi* and lower in shrubland and grassland (Table 1). Stands with lower rates of severe disturbances have a more diverse structure represented in the number of stories, coarse woody debris and snags. *N. dombeyi,* in absence of disturbances, suppresses *A. araucana* growth and dominates the canopy.

The structural stage of our method gives information about the habitat diversity and dynamic of the ecosystem. Parameters like coarse woody debris, story number and density allow predictions to be made about habitat and microhabitat diversity and characteristics. Regeneration and size distribution of dominant trees are indicators of successional patterns. In general terms, for some authors, structure is the most important variable to be assessed because it determines ecosystem function.

Composition

The study case results show that floristic plant communities are associated with structural patterns (Table 1), but in some cases different plant communities are present in the same physiognomic types. Cluster analysis helps to clarify plant communities and validate the results of tabular comparison. Species richness is similar in all communities, only secondary forests of *N. dombeyi* and grassland have lower values (Table 1). Even when species richness in the area seems low, taxic diversity presents an unusual number of families and genera, which could be products of higher endemism rates.

Our method for composition proved to be efficient in capturing species richness (alpha diversity) and patterns of distribution of floristic plant communities. Rare species, indicator species and relative abundance of species are captured. Further modification could improve sampling statistical performance without damaging the advantages of easy and quick sampling. Randomization and statistical stratification of the relevés by physiognomic types would help to make quantitative inferences about species diversity. Plant communities can be classified in phytosociological hierarchical systems, but this option is constrained by the availability of regional classification studies.

Application Considerations

The application showed that the method was feasible to apply to Chilean Protected Areas. Not major problems were found in using the sampling techniques. Remote sensing data is available for all Chilean territory, so physiognomic classification can be achieved. The National Vegetation Inventory has released new information already processed. Vegetation maps 1:50.000 represent PA. GIS must be used to process the data, so cost could arise.

Structural attributes are easy to sample even by rangers or people without technical background. With a good sampling design, a broad area can be covered with a minimum cost in instruments and work hours. Floristic stage involved a more time consuming sampling. Taxonomic classification requires expertise for field recognition, but national herbariums have a good collection of plants than can make easier to identify the specimens.

The main problem of our design is the qualitative approach in information collection. This may imply difficulties in measuring changes in vegetation with statistical rigor. Further work, using remote sensing technology and sampling design, must be done to achieve this goal.

External issues can also affect the applicability of the method. Political and economical restrictions of the public institutions involved in PAs management can weak this method performance in Chile or other developing countries.

Conclusions

1. Vegetation is a useful indicator of biodiversity for the EIA baseline in PAs. To assess vegetation baseline, we propose a multiscale method, using three stages: physiognomic, structure and composition.

2. The three stages are correlated with basic ecological parameters. Structural diversity, habitat diversity, ecotones, edge effect, vegetation dynamic and others can be assessed using the multiscale method.

3. The multiscale method proved to be more efficient to capture whole ecosystem diversity than the one-scale methods. It provides the information necessary to satisfy the requirements of biodiversity assessments.

4. The three stages give flexibility to the method. The detail level will depend on the objectives and the impacted area. The application of the method is feasible in Chilean PAs and other countries.

References

Armesto, J. J.; Smith-Ramírez C.; León, P. and M. K. Arroyo, 1992. Biodiversidad y Conservación del Bosque Templado en Chile. Ambiente y Desarrollo. Vol. 8, pp 19-24. Santiago.

Benoit, I. 1989. Libro Rojo de la Flora Terrestre de Chile. Corporación Nacional Forestal. Ministerio de Agricultura. República de Chile. Santiago.

Bisby, F. 1995. Characterization of biodiversity. In: Global Biodiversity Assessment. Ed. Heywood, V.H. United Nations Environment Programme. Cambridge University Press. New York.

Casertano, L. 1963. General characteristic of active Andean volcanoes and a summary of their activities during recent centuries. Bulletin of the Seismological Society of America. Vol. 53:6. USA.

Ceballos-Lascuráin, H. 1996. Tourism, ecotourism, and protected areas. IV World Congress on National Paks and Protected Areas. IUCN.

Conesa, V. 1995. Guía metodológica para la evaluación del impacto ambiental. Mundi-Prensa. Madrid.

Donoso, 1993. Bosques templados de Chile y Argentina. Variación, estructura y dinámica. Editorial Universitaria. Santiago.

Eskuche, U. 1973. Estudios Fitosociológicos en el Norte de Patagonia. Investigación de algunos factores de ambiente en comunidades de bosque y chaparral. Phytocoenologia. Stuttgart- Lehre. Vol. 1 (1) 64-113.

Finckh, M. 1996. Die Wälder des Villarrica-Nationalparks (Südchile)-Lebensgemeinsschaften als Grundlage für ein Schutzkonzept. Dissertationes Botanicae. Band 259. J. Cramer. Berlin-Stutgart.

Forman, R. T. T. 1995. Land mosaics: the ecology of landscape and regions. Cambridge University Press. Cambridge.

Fosberg, F. R. 1967. A classification of vegetation for general purposes. In Peterken, G.F. IBP Handbook Nº4. Guide to check sheet for IBP areas. Blackwell Scientific Publications. Oxford.

Gajardo, R. 1994. La vegetación natural de Chile. Clasificación y distribución geográfica. Editorial Universitaria. Santiago.

Greene, S. E. 1984. Botanical Baseline Monitoring in Research Natural Areas in Oregon and Washington. In: Research Natural Areas: Baseline Monitoring and Management. Symposium Proceedings. General Technical Report INT-173. Forest Service, USDA. Ogden.

Grossman, D. H.; Faber-Langendoen, D.; Weakley, A. S.; Anderson, M.; Bourgeron, P.; Crawford, R.; Goodin, K.; Landaal, S.; Metzler, K.; Patterson; K., Pyne, M.; Reid, M. and Seddon, L. 1998. International classification of ecological communities: Terrestrial Vegetation of United States. VolumeI. The National Vegetation Classification System: Development, Status and Applications.The nature Conservancy, Arglinton, Virginia.

Krebs, C.J. 1994. Ecology: The experimental analysis of distribution and abundance. Harper Collins College Publishers.

Lara, A.; Donoso, C. and Aravena, J. C. 1995. La conservación del bosque nativo de Chile: problemas y desafíos. In: Armesto, J. J.; Villagrán, C. y Arroyo, M. K. eds. Ecología de los bosques nativos de Chile. Editorial Universitaria. Santiago.

Lazo, A. 1996. La inversión más natural, impulso del ecoturismo en áreas silvestres protegidas. Chile Forestal. Abril. pp 34-36.

McNeely, J. A.; Harrison, J. and Dingwall, P. 1994. Protected Areas in the Modern World. In: Protecting nature: regional reviews of protected areas. Mc Neely, J. A.; Harrison, J. and Dingwall, P. eds. IUCN, Gland.

Mueller-Dombois, D. and Ellenberg, H. 1974. Aims and Methods of Vegetation Ecology. John Wiley & Sons. New York.

O'Neill, R. V. and King, A. W. 1998 Homage to St. Michael; or, Why are there so many books on scale? In: Ecological scale: theory and applications. Peterson, D. L. and Parker, V.T. eds. Columbia University Press. New York.

Pauchard, A. 1998. La linea de base en la Evaluación de Impacto Ambiental en áreas silvestres protegidas. Bases metodológicas para el componente vegetacional. Memoria de Título. Facultad de Ciencias Forestales. Universidad de Concepción.

Peralta M. 1975. Tipificación de los Suelos en la formación forestal Araucaria-Lenga en el Parque Nacional Conguillío. Bol. Nº 31. Universidad de Chile. Santiago.

Peterson, D. L. and Parker, V.T. eds. 1998. Ecological scale: theory and applications. Columbia University Press. New York.

Rivas, H. 1994. Hacia un desarrollo turístico de los ambientes naturales en Chile. Ambiente y Desarrollo. Santiago.

Shimwell, D. W. 1972. The Description and Classification of Vegetation. Sidgwick & Jackson. London.

Stork, N. E. and Samways, M. J. 1995. Inventorying and Monitoring. In: Global Biodiversity Assessment. Ed. Heywood, V.H. United Nations Environment Programme. Cambridge University Press. New York.

Turner, M. G. and Gardner, R. H., 1991. Quantitative methods in landscape ecology: An introduction. In: Quantitative methods in landscape ecology: The analysis and interpretation of landscape heterogeneity. Turner, M. G. and Gardner, R. H. eds. Springer-Verlag. New York.

Veblen, T. T. 1982. Regeneration patterns in *Araucaria araucana* forest in Chile. Journal of Biogeography Vol. 9: 11-20.

Veblen, T. T., Kitzberger, T., Burns, B. R. and Rebertus, A. J. 1995. Perturbaciones y dinámica de regeneración en bosques andinos del sur de Chile y Argentina. In: Armesto, J. J.; Villagrán, C. and Arroyo, M. K. eds. Ecología de los bosques nativos de Chile. Editorial Universitaria. Santiago.

Villarroel, P. 1992. Areas silvestres protegidas: ¿Bienvenida a capitales privados? Ambiente y Desarrollo. Diciembre. Santiago.

Shrub-Steppe Vegetation Trend, Middle Fork Salmon River, Idaho

James M. Peek

Abstract—The Middle Fork Salmon River drainage of the Frank Church River-Of-No-Return Wilderness has a history of livetock grazing from 1890 to1950, and changes in grazing pressure from native ungulates. High mule deer (*Odocoileus hemionus*) populations occurred between 1940 and 1960, and high elk (*Cervus elaphus*) populations occurred in the 1990s. This paper describes the shrub-steppe communities inside and adjacent to exclosures in the Middle Fork. Also presented is the current vegetative appearance at sites photographed in 1925, 1968, and 1988. Comparisons of plant species composition and characteristics, plus knowledge of grazing history, provide a basis for interpreting vegetation change and relationships to herbivore populations.

The Frank Church River-of-No-Return Wilderness has an extensive history of grazing along the Middle Fork of the Salmon River and its major tributaries, dating back to the late 1800s. At Cabin Creek, a tributary to Big Creek approximately 15 miles west of its confluence with the Middle Fork, grazing was initiated in the early 1890s. Cattle were ranched from 1902 to the early 1950s. Saddle and pack stock were grazed from the early 1950s until 1973, when the USDA Forest Service acquired it (Hartung 1978). Sheep, cattle and horses were grazed in the Thomas Creek area beginning in the 1920s, until the Idaho Department of Fish and Game bought the homesteads in the early 1940s (Hamilton 1990).

Obvious evidence of the effects of past grazing on vegetation exists in areas such as at Cabin Creek, where wormwood (*Artemisia dracunculus)*, an increaser, is prevalent on south-facing slopes next to abandoned hayfields and pastures that were created in the riparian zones. Exotic species such as spotted knapweed (*Centaurea maculosa*) have invaded some areas that have not been grazed appreciably in the last half-century, but thus far the presence of these aggressive invaders is localized. Currently, grazing of pack and saddle stock is concentrated around inholdings, and effects on plant communities are considered in management.

The FCRNRW has a history similar to most of the intermountain west, wherein fire suppression became effective in the 1940s (Wellner 1970). Current fire management policies allowing fires to burn under most circumstances in the FCRNRW (USDA Forest Service draft environmental impact statement, Frank Church River-Of-No-Return Wilderness, 1998) may eventually reduce the influences of past fire suppression.

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A series of exclosures were established in the FCRNRW in the late 1940s and early 1950s to assist in determining the effects of grazing by livestock and wildlife (mainly mule deer, *Odocoileus hemionus*) on vegetation. These exclosures were examined at intervals through the 1960s and then largely abandoned. Some of the fences were removed, while others were left intact.

Examinations of exclosure sites at Hood Ranch, Little Loon Creek, Cow Creek, Brush Creek, Reservoir Creek, and Cave Creek in the Middle Fork of the Salmon River drainage were completed between June 1988 and July 1992 (figure 1). The descriptions provide comparisons of vegetative composition inside and outside of exclosures that were established to exclude livestock and big game at least 30 years ago. Additionally, sites that were photographed in 1925, 1968, and 1988 in Brush Creek and across from Reservoir Creek provided some comparisons of shrub cover through time.

Methods

We randomly established a transect of twenty, 2 x 5 dm plots on representative sites inside exclosures and on similar adjacent sites. Plots were 1 m apart. When more than one

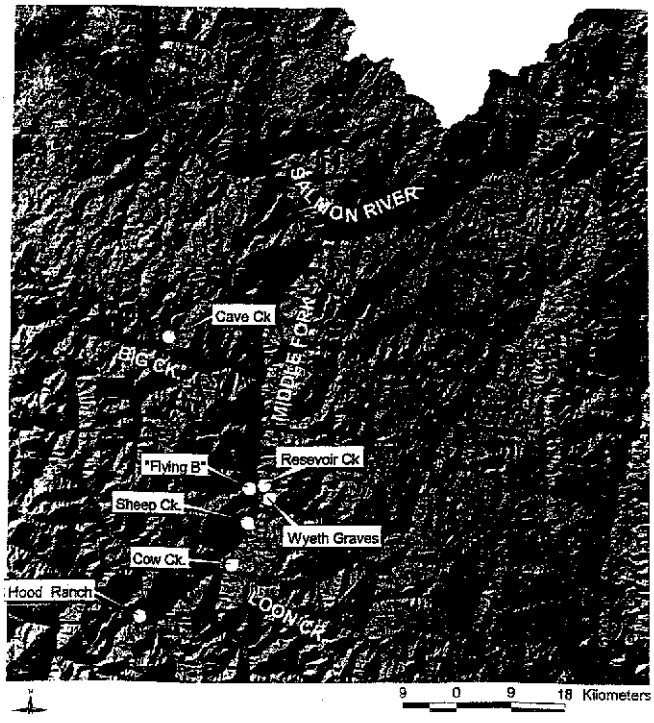

Figure 1—Middle Fork of the Salmon River exclosure locations.

vegetative type or topographical situation was present in an exclosure, paired plots were established inside and outside for each type where possible. We examined vegetation to determine if the fences appeared to influence composition and avoided locations immediately adjacent to fences.

Canopy coverage of each species in each plot was estimated to be in one of six standard categories: 1) 0-5%; 2) 5-25%; 3) 26-50%; 4) 51-75%; 5) 76-95%; 6) 96-100%. Canopy coverage is defined as the vertical projection to ground level of the maximum aerial canopy of the species within the sample plot (Daubenmire 1959).

Woody plant density was measured in 20, $4m^2$ circular plots (1.13 m radius) adjacent to the herbaceous transects. Counts of stems were made at ground level inside plots. Where individual plants had crowns with stems rising just below or at ground level and were obviously one plant, one plant was recorded. This occurred with antelope bitterbrush *(Purshia tridentata*), curl-leaf mountain mahogany (*Cercocarpus ledifolius*), big sagebrush (*Artemisia tridentata var. vaseyana*), currants (*Ribes cereum*, *R. viscossimum*), heath goldenrod (*Ericameria nauseosa)*, green rabbitbrush (*Chrysothamnus viscidiflorus*) and mallow ninebark (*Physocarpus malvaceus)* in this area. Height of a representative plant of each species in the plot was recorded. Dead plants were recorded when present, and percentage of decadent growth on each shrub was estimated.

Twigs, representing current annual growth (CAG) over 1 cm long, were counted for each species inside each plot. The plot was envisioned as a cylinder, and twigs within that cylinder were counted whether they originated from stems that occurred inside or not. A twig density was calculated to serve as a partial measure of productivity. Lengths of 50 or more randomly selected twigs were measured, air-dried and individually weighed. The entire collection was then weighed and oven-dried at 70° C for 24 hours and reweighed. The ratio of oven-dried weight to air-dried weight was multiplied for each twig weight to convert to the oven dried weight for each individual twig. Photographs were taken of all stands, and a description of the location of each transect was recorded. Plant nomenclature follows Hitchcock and Cronquist (1973) and the U.S. Department of Agriculture Natural Resource Conservation Service National Plant Database (1998 website: plants.usda.gov/plantproj/plants/index).

Data analysis used midpoints of the coverage estimation classes, and standard descriptive statistics for each species on the site were obtained using SAS-PC or STATISTIX. T-tests were used to determine significant differences (P=0.05) for selected vegetative parameters inside and outside of the exclosures. Coverage and density data were transformed using log (number + 1) to account for non-normal distributions. A Wilcoxon test was also used to compare with the t-tests, but no changes in conclusions resulted from the t-test comparisons.

Results

Cave Creek Exclosure

This site included a formerly exclosed area and adjacent areas that were unprotected. The site was a gently sloping, west-facing exposure. The major difference between the formerly exclosed portion and adjacent site was in the shrub component (table 1). Big sagebrush density was approximately 2.5 times greater on the formerly exclosed site. Dead sagebrush stem density was also greater The height of big sagebrush plants on the formerly exclosed site was double that of plants on unprotected areas.

Antelope bitterbrush heights were significantly greater on the formerly exclosed site, but stem densities were nearly

Table 1—Vegetative characteristics of the Cave Creek exclosure site.

Herbaceous species (coverage >5%)	Inside (Canopy cover ± S.D.)	Outside (Canopy cover ± S.D.)	T-test T	T-test P
Arrowleaf balsamroot *Balsamorhiza sagittata*	6.4 ± 14.5	4.6 ± 11.7	0.48	.631
Bluebunch wheatgrass *Pseudoroegneria spicata*	19.8 ± 27.7	14.8 ± 27.9	0.45	.656
Cheatgrass *Bromus tectorum*	0.3 ± 0.8	20.0 ± 23.6	6.60	.0001
Letterman's needlegrass *Stipa lettermani*	6.5 ± 13.8	8.8 ± 15.1	0.77	.443
Western yarrow *Achillea millifolium*	2.1 ± 4.5	5.0 ± 6.8	1.51	.142
Shrubs				
Big sagebrush (*Artemisia tridentata*)				
Height (cm)	160.5 ± 25.5	47.8 ± 16.0	8.33	.0001
Stems/m^2	0.63 ± 1.00	0.25 ± 0.40	4.00	.0003
Dead stems/m^2	0.33 ± 0.23	0.01 ± 005	6.02	.0001
Twigs/m^2	104.6 ± 84.9	21.6 ± 34.7	4.78	.0001
Antelope bitterbrush (*Purshia tridentata*)				
Height (cm)	134.8 ± 35.8	85.3 ± 24.8	4.99	.0001
Stems/m^2	0.05 ± 0.1	0.05 ± 0.10	.47	.6430
Dead stems/m^2	0.01 ± 05	0		
Twigs/m^2	2.72 ± 8.3	7.2 ± 14.9	1.11	.2792

identical. Twig density was greater outside than on the formerly exclosed site, but the difference was not significant. Dead stem density was negligible outside and very low inside for this species.

The major difference in the herbaceous union was the high coverage of cheatgrass (*Bromus tectorum*) outside of the formerly exclosed area, and the very low coverage inside. The high standard deviation outside reflected the patchy distribution of this species. Coverage of other species was not appreciably different, but green weight production of bluebunch wheatgrass (*Pseudoroegneria spicata*) was 16.7 gm/m^2 inside the exclosure and 29.5 gm/m^2 outside of the exclosure at the time of measurement, indicating a more vigorous grass community outside.

The differences between the formerly exclosed site and the unprotected site adjacent strongly suggest that the area had been disturbed. The consistency of bitterbrush density suggested this species was a dominant, and with the high coverage of bluebunch wheatgrass, indicated an antelope bitterbrush/bluebunch wheatgrass habitat type (Hironaka et al. 1983, Mueggler and Stewart 1980). The high amount of big sagebrush in the formerly excluded area suggested that grazing disturbance in past periods allowed the increase of this species, which was then protected from game browsing by fencing; this in turn essentially retarded succession by allowing retention of the sagebrush. Big sagebrush was still undergoing substantial mortality inside the formerly exclosed area, but mortality appeared to persist at a low level outside. The greater coverage of cheatgrass outside of the exclosure may be explained by the disturbance of both past livestock and perhaps by ongoing wildlife grazing, and this species may diminish in coverage on this site over time. The Housley Ranch, started in the early 1900s in Cave Creek, was abandoned about 1919 (Hartung 1978). The long history of livestock grazing in the Cabin Creek area immediately downstream from Cave Creek suggests that livestock grazing was an important influence on vegetation trends in the Cave Creek area as well.

"Flying B" Exclosure

The exclosure was established on an east-facing site in 1949. Bitterbrush was planted inside the exclosure. The outside transect was established north of the exclosure, which occurred on the ridge above the airstrip owned by the "Flying B". This area received extensive use by mule deer and is also grazed by horses.

The most striking aspect of the site was the dominance of balsam root (*Balsamorhiza sagittata*), both inside and outside the exclosure (table 2). The low coverage of bluebunch wheatgrass, lesser spikemoss (*Selaginella densa*), Idaho fescue and needle-and-thread outside of the exclosure reflected responses to grazing pressure when compared with vegetation inside the exclosure. Threetip sagebrush

Table 2—Vegetative characteristics of the "Flying B" exclosure site.

Herbaceous species (coverage >5%)	Inside S	Inside N	Outside N	T-test	
	(Canopy cover ± S.D.)			T	P
Arrowleaf balsamroot *Balsamorhiza sagittata*	12.6 ± 26.8	34.8 ± 39.3	21.6 ± 20.3	0.98	.329
Bluebunch wheatgrass *Pseudoroegneria spicata*	12.5 ± 23.2	12.9 ± 22.3	0.4 ± 0.9	3.51	.0017
Cheatgrass *Bromus tectorum*	32.4 ± 31.1	16.0 ± 26.4	4.5 ± 9.2	.582	.563
Field chickweed *Cerastium arvense*	0	10.1 ± 21.6	4.7 ± 6.4	.046	.963
Idaho fescue *Festuca idahoensis*	14.0 ± 26.6	7.1 ± 13.8	0.3 ± 0.8	14.96	.056
Longleaf phlox *Phlox longifolia*	3.4 ± 6.0	1.3 ± 3.4	0.5 ± 1.1	.686	.497
Lesser spikemoss *Selaginella densa*	26.3 ± 39.2	22.6 ± 38.6	0		
Needle-and threadgrass *Hesperochloa comata*	2.3 ± 8.4	10.8 ± 28.7	0		
Sandberg bluegrass *Poa secunda*	0.1 ± 0.6	3.0 ± 8.8	0		
Shrubs					
Antelope bitterbrush (*Purshia tridentata*)					
Height (cm)	0	168.8 ± 32.0	119.0 ± 53.8	2.64	.012
% decadence	0	24.5 ± 16.4	59.5 ± 15.4	6.97	.0001
Twig lengths (cm)	0	1.25[1]	4.75 ± 2.1	8.237	.0001
Threetip sagebrush (*Artemisia tripartita)*					
Height (cm)	0	64.3 ± 14.8	19.5 ± 7.8	10.56	.0001
% decadence	0	20.7 ± 16.2	20.0 ± 16.9	0.11	.907
Twig lengths (cm)	0	40.8 ± 5.0	8.0 ± 3.5	5.93	.0001

[1]No twigs over 1.25 cm long. One plant, 35 cm high with a 10 cm leader, was established on bare soil inside the exclosure.

(*Artemisia tripartita*), a palatable deer forage, outside of the exclosure was 30% of the height inside the exclosure, and twig lengths were 47% as long outside as they were inside.

Antelope bitterbrush plants inside the exclosure were tall, contained moderate amounts of dead stems and were essentially unproductive. No current annual growth was over 1 cm. In contrast, antelope bitterbrush plants outside were lower and contained large amounts of dead stems, and CAG averaged 4.8 cm long, the converse of threetip sagebrush, which was shorter and less productive outside than inside.

The site showed evidence of extensive current and past grazing. I hypothesize that this site is a threetip sagebrush/ Idaho fescue habitat type, with antelope bitterbrush being seral or existing at low density in the undisturbed state. Antelope bitterbrush was essentially not reproducing on the site (one plant 35 cm tall had established on bare soil inside the exclosure). Deer use was probably responsible for the lower heights and shorter twig lengths of threetip sagebrush and for the lower heights and longer twig lengths of bitterbrush outside the exclosure when compared with plants located inside. This suggests that threetip sagebrush was more sensitive to grazing pressure than antelope bitterbrush. An alternative explanation for the low heights and vigor of threetip sagebrush is that both deer and horses were grazing it, while only deer used the antelope bitterbrush. Herbaceous conditions outside the exclosure were attributed to grazing by horses. This raises questions about the conditions that allowed for the prevalence of antelope bitterbrush on this site which may be attributable to past grazing history. The antelope bitterbrush may have been planted in areas where that species is not especially suited, as the antelope bitterbrush inside the exclosure was obviously not vigorous and had not been so for years.

Sheep Creek Exclosures

The small exclosure (20 X 20 feet) inside the major exclosure was established in 1930, while the larger exclosure was established in 1961, thereby allowing comparisons of 59 and 27 years of protection with unprotected conditions. Crested wheatgrass (*Agropyron cristatum)* was planted inside the small exclosure, and 15 plants remained (table 3). There were 10 live and four dead antelope bitterbrush plants in the small exclosure, and they averaged 226.5 cm tall, as compared with the 165.8 cm height of seven antelope bitterbrush plants immediately adjacent on an unexclosed site. Three heath goldenrod plants occurred in the exclosure, 95, 95 and 125 cm tall.

Perhaps the most striking difference in the herbaceous union inside and outside the small exclosure was the dominance of needle-and-thread outside and the higher coverage of harryseed lomatium (*Lomatium foeniculatum*), longleaf phlox (*Phlox longifolia*) and tall tumble mustard (*Sisymbrium altissimum*) inside. Just what this was attributable to is unclear, but different grazing regimes, past and present, and the relatively small size of the exclosure, which may enhance moisture retention, may be responsible.

The larger exclosure provided similar comparisons and included more species (table 4), but harryseed lomatium was less prevalent in the large exclosure than in the smaller one. Bushy blazingstar (*Mentzelia dispersa),* was common on this site and was not observed elsewhere in the Middle Fork exclosures. If grazing is to be considered the major factor influencing differences between excluded and unprotected areas in this canyon, why should parsnip-flowered buckwheat (*Eriogonum heracleoides)* and longleaf phlox, both relatively unpalatable half-shrubs, be more prevalent inside

Table 3—Vegetative characteristics of the small Sheep Creek exclosure site.

Herbaceous species (coverage >5%)	Inside (Canopy cover ± S.D.)	Outside (Canopy cover ± S.D.)	T-test T	T-test P
Bluebunch wheatgrass *Pseudoroegneria spicata*	3.4 ± 9.3	0.8 ± 3.3	1.18	.248
Cheatgrass *Bromus tectorum*	4.4 ± 9.5	1.4 ± 3.4	0.96	.3509
Fennel-leaved desert parsley *Lomatium foeniculatum*	6.3 ± 11.9 .	.03 ± 0.8	2.384	.0255
Lesser spikemoss *Selaginella densa*	54.5 ± 39.9	31.6 ± 38.1	1.103	.2771
Longleaf phlox *Phlox longifolia*	20.8 ± 30.2	0		
Needle-and-Thread *Hesperochloa comata*	3.8 ± 6.7	26.3 ± 28.3	3.32	.0019
Shrubs				
Antelope Bitterbrush (*Purshia tridentata*)				
Height (cm)	226.5 ± 88.3	165.8 ± 66.3	1.134	.2748
Number of live plants	10	0		
Number of dead plants	4	0		

Table 4—Vegetative characteristics of the large Sheep Creek exclosure site.

Herbaceous species (coverage >5%)	Inside (Canopy cover ± S.D.)	Outside (Canopy cover ± S.D.)	T-test T	T-test P
Bluebunch wheatgrass *Pseudoroegneria spicata*	4.4 ± 19.6	0.8 ± 3.4	0.32	.748
Bushy blazingstar *Mentzelia dispersa*	6.4 ± 13.8	4.1 ± 14.1	.791	.4348
Cheatgrass *Bromus tectorum*	4.4 ± 9.5	1.4 ± 3.4	0.96	.3509
Fennel-leaved desert parsley *Lomatium foeniculatum*	0	0.3 ± 0.77		
Lesser spikemoss *Selaginella densa*	45.9 ± 38.3	21.1 ± 29.0	2.097	.0427
Longleaf phlox *Phlox longifolia*	6.4 ± 9.6	0.1 ± 0.6	3.962	.0005
Needle-and-Thread *Hesperochloa comata*	16.6 ± 23.9	29.8 ± 27.7	.9575	.3444
Parsnipflower buckwheat *Eriogonum heracleoides*	4.9 ± 21.8	0		
Shrubs				
Antelope bitterbrush (*Purshia tridentata)*				
Height (cm)	209.8 ± 80.3	195 ± 86.8	.833	.4084
Number of live plants	43			
Number of dead plants	13			

the exclosures than outside? Other factors, including competition for moisture between plant species, successional patterns of vegetation following protection from different kinds of disturbances, different soil and moisture regimes among the various exclosures (this site is the highest and is located on a ridgetop) and climatic change from periods of relative drought to periods of high precipitation were probably involved.

Forty-three live antelope bitterbrush plants occurred inside the large exclosure and were comparable in height to plants inside the small exclosure. Dead plants constituted 23% of the standing antelope bitterbrush stems. Needle-and- thread characterized the understory inside the exclosure, while a large variety of species constituted relatively equivalent proportions of the vegetative cover outside. Cheatgrass occurred primarily beneath bitterbrush plants, while needle-and-thread occurred in openings between shrubs, where effects of shade and perhaps moisture competition were less. The higher coverage of lesser spikemoss inside this exclosure was again considered a reflection of the lack of disturbance of the soil surface. This site was considered primarily a bitterbrush/bluebunch wheatgrass habitat type. This may be the most severe site enclosed in the general area.

Reservoir Creek Game Exclosures

The Reservoir Creek exclosures were established in 1949. The "game" exclosure was located on the west and southerly exposed slopes south of Reservoir Creek and contained a variety of sites and at least two habitat types. Outside replications on comparable adjacent sites were difficult to locate; finally, one outside replicate of the bitterbrush stand in the exclosure was located on an adjacent slope north of the exclosure.

The crest of the ridge inside the exclosure was considered a threetip sagebrush/Idaho fescue habitat type (table 5). No replicates were available for this community adjacent to the exclosure. The aspect was northwest. The community consisted of a vigorous stand of Idaho fescue, with bluebunch wheatgrass, Sandberg bluegrass (*Poa secunda*), hawksbeard (*Crepis atrabarba*), threetip sagebrush, and antelope bitterbrush all comprising between 3% and 10% canopy coverage.

The rest of the exclosure faced south to southwest and probably contained an antelope bitterbrush/bluebunch wheatgrass habitat type on the more xeric sites. The higher canopy coverage values of bluebunch wheatgrass and antelope bitterbrush outside the exclosure were from the adjacent slope and may reflect less severe growing conditions there. Antelope bitterbrush plants in the exclosure were most decadent on sites with the highest grass coverage. The youngest and thriftiest plants inside this exclosure occurred on the most severe sites, where grass cover was lowest. There were few plants less than 30 cm tall, which indicated seedling establishment, but antelope bitterbrush plants were more commonly reproducing by layering. Plants outside the exclosure showed three to four times the leader growth of those inside and were intensively browsed. Dead and decadent antelope bitterbrush was significantly greater inside than outside the exclosure, with the difference being related to associated grass cover. Mule deer were the major users of this site, and a few pellet groups were found inside the exclosure.

Reservoir Creek Stock Exclosure

This exclosure was on a gentle slope below the game exclosure and further south. It appeared to be an antelope bitterbrush/bluebunch wheatgrass habitat type. There was

Table 5—Vegetative characteristics of the Reservoir Creek game exclosure site.

East end of exclosure Herbaceous species (coverage >5%)	Inside (Canopy cover ± S.D.)	Outside	T-test T	 P
Bluebunch wheatgrass *Pseudoroegneria spicata*	23.0 ± 31.7	15.6 ± 22.4	0.31	.759
Cheatgrass *Bromus tectorum*	4.4 ± 9.5	5.4 ± 6.6	0.77	.452
Heath goldenrod *Ericameria nauseosa*	1.0 ± 28.5	0.8 ± 3.4	1.14	.269
Lesser spikemoss *Selaginella densa*	15.0 ± 30.9	2.6 ± 8.9	1.91	.0716
Needle-and-Thread *Hesperochloa comata*	0.8 ± 3.4	12.0 ± 24.9	2.02	.058
Sandberg bluegrass *Poa secunda*	3.4 ± 6.0	0.1 ± 0.6	1.94	.067
Shrubs				
Antelope bitterbrush (*Purshia tridentata*)				
Height (cm)	167.0	130.5	2.72	.0135
% decadent	22.5	28.0	1.00	.3299
Twig length (cm)	1.25	5.24	3.83	.0004

North and west side of exclosure Herbaceous species (coverage >5%)	Inside S	Inside N	Outside N (Canopy cover ± S.D.)	T-test T	 P
Bluebunch wheatgrass *Pseudoroegneria spicata*	10.5 ± 16.9	7.3 ± 20.8	23.9 ± 26.2	2.13	.0468
Heath goldenrod *Ericameria nauseosa*	0	4.6 ± 14.	4.7 ± 20.1	0	1.00
Slender hawksbeard *Crepis atrobarba*	6.5 ± 14.5	0	0		
Idaho fescue *Festuca idahoensis*	47.9 ± 27.7	0	0		
Sandberg bluebrass *Poa secunda*	6.8 ± 6.9	0.1 ± 0.6		4.65	.0002
Shrubs					
Antelope bitterbrush (*Purshia tridentata*)					
Height (cm)	104.5[1]	123.2[2]	104.5	.46	.6513
% decadent	16[1]	36[1]	21	2.54	.020
Twig length (cm)	1.25	1.25	5.75	7.61	.0001

[1]Severe site without significant grass understory.
[2]Less severe site with moderate grass understory
[3]Inside(n) is near ridge, more mesic site than inside(w) which is on a steep facing south slope.

abundant deer use in this exclosure and some horse use; it was apparently used as a corral by hunters at some time in the recent past. On the east side, bluebunch wheatgrass exhibited the highest coverage values, both on a representative site that was replicated outside and on an unreplicated severe site inside (table 6). Cheatgrass was present on the severe site but not on the replicated sites. Needle-and-thread coverage was higher on the unprotected site than inside, while heath goldenrod showed higher coverage inside than outside. The more severe site had lower coverage values of antelope bitterbrush, and big sage was present, suggesting a big sagebrush/bluebunch wheatgrass habitat type. Needle-and-thread grass may be a high seral dominant, which ultimately would be replaced by bluebunch wheatgrass on this site.

The south side of this exclosure and the adjacent unprotected site were dominated by needle-and-thread, with antelope bitterbrush and big sagebrush in the overstory. Although big sage was not recorded in the plots, it occurred on the site and was taller, less decadent and exhibited longer leader growth inside the exclosure than outside. The plants outside the exclosure were extensively browsed.

Wyeth Burial Site

This burial site, excluded from grazing by a low pole fence, is on a flat bench across from the "Flying B" on Idaho Fish and Game Department land and is approximately 3.3 by 6.6 m in size. It was surrounded by a big sagebrush community, but only one small sagebrush plant occurred inside the

Table 6—Vegetative characteristics of the Reservoir Creek stock exclosure site.

Herbaceous species (coverage >5%)	Inside (low)	Inside (high)	Outside (high)	T-test	
	(Canopy cover ± S.D.)			T	P
Ballhead sandwort *Arenaria congesta*	0	7.1 ± 9.7	11.0 ± 14.7	.26	.8008
Bluebunch wheatgrass *Pseudoroegneria spicata*	18.3 ± 30.5	0	0		
Cheatgrass *Bromus tectorum*	6.6 ± 23.8	0	0		
Needle-and-Thread *Hesperochloa comata*	0	42.6 ± 25.4	57.1 ± 25.6	1.94	.0676
Sixweeks fescue *Vulpia octoflora*	0	15.5 ± 21.1	7.9 ± 6.7	1.82	.0842
Shrubs					
Big sagebrush (*Artemisia tridentata*)					
Height (cm)	129.0 ± 23.8	110.3 ± 47.3	0	2.35	.0296
% decadent	36.0 ± 20.4	46.5 ± 17.2	0	1.69	.1077
Twig length (cm)	13.0 ± 5.3	9.3 ± 3.0	0	4.64	.0001

fence. Needle-and-thread was dominant, with coverage estimated at over 80%. Cheatgrass was present, with coverage estimated at 10%. Some bluebunch wheatgrass was present at 5% coverage. One small big sagebrush plant was present. Three dead heath goldenrod plants occurred on this site. There were no forbs present. This greatly disturbed site provided evidence that needle-and-thread was seral to bluebunch wheatgrass on these benches. If this is the case, at least some of the benches along the river were probably a big sagebrush/bluebunch wheatgrass habitat type, to which this site would presumably succeed if left undisturbed.

Sunflower Creek (Hood Ranch) exclosure

The fence at this site was torn down in the mid-1980s, but the outline of the exclosure was readily apparent from a line of bluebunch wheatgrass along one side, wire laying on the ground near one corner and trails along other sides. It was 0.4 ha in size. An 0.4 ha plot was established adjacent to the exclosure site for comparisons.

The herbaceous union did not show significant differences in coverage of bluebunch wheatgrass, cheatgrass or arrowleaf balsamroot, the three major plant species (table 7). The slightly higher coverage of cheatgrass, and presence of field chickweed (*Cerastium arvense*) outside of the exclosure, were offset by the slightly higher coverage of annual cruciferae inside. A significant difference in bluebunch wheatgrass seed stalk heights was apparent on the exclosure site (mean 75.7 cm) and the adjacent site (mean 69.2 cam, T= 2.9734, P=.0039).

The shrub component showed rather dramatic differences inside and outside the exclosure site. Live antelope bitterbrush was nearly absent outside the exclosure site in its vicinity. Within the exclosure site, 47 of 90 plants were alive, while 3 of 66 were alive adjacent to the site. One of the three plants outside was 34 cm tall, while the other two were over 200 cm tall. A variety of size classes were represented inside the exclosure. Fifteen of 20 heath goldenrod plants were alive inside the exclosure site, while 28 of 42 were alive outside, an insignificant difference. These plants were all heavily browsed. Mountain sagebrush was represented by three plants inside the exclosed site and was not found on the adjacent plot. Heath goldenrod was taller inside than on the adjacent site.

This site was considered an antelope bitterbrush/bluebunch wheatgrass habitat type, based on the presence of these species on the exclosed site. The reduction in shrub components outside was attributable to the site being a major elk and mule deer wintering area. Since the shrub component was so depauperate on the sites that were consistently exposed to browsing, the trend was towards a bluebunch wheatgrass/balsamroot community. As evidence of antelope bitterbrush disappears, interpretation of the successional status in the absence of the exclosed site will become progressively more difficult.

The ridge above this exclosure site was burned in the Mortar Fire of 1981. On the most southerly exposed sites, cheatgrass and arrowleaf balsam root predominated, and antelope bitterbrush plants were all dead. However, on other sites where Idaho fescue was present, sprouting from the rootcollars of many burned antelope bitterbrush plants was observed. The whole area was traditional mule deer winter range and was probably grazed by livestock during the period when the homesteads were occupied. Bud Hamilton, a long-time Forest Service employee with extensive knowledge of this area, said that sheep, cattle and horses grazed the Thomas Creek area in the 1920s and 1930s. The Idaho Department of Fish and Game bought the Hood Ranch in the early 1940s to secure the mule deer winter range by removing the livestock. In 1966, there were hardly any elk in the area, according to Hamilton. Current elk population for the Middle Fork hunting unit 27 is estimated at 5,224+255 by Idaho Department of Fish & Game (Scott 1999).

Little Loon Creek exclosure

This one-acre site, established in 1964, was burned in 1981, but the charcoal remnants of the wooden railings of the exclosed site outlined the exclosure. It was examined in

Table 7—Vegetative characteristics of the Hood Ranch exclosure site.

Herbaceous species (coverage >5%)	Inside (Canopy cover ± S.D.)	Outside (Canopy cover ± S.D.)	T-test T	T-test P
Annual mustards *Crucifera* spp.	5.3 ± 9.3	1.01 ± 1.1	1.18	.244
Arrowleaf balsamroot *Balsamorhiza sagittata*	14.4 ± 32.4	8.5 ± 20.2	.418	.6778
Bluebunch wheatgrass *Pseudoroegneria spicata*	15.5 ± 29.3	17.0 ± 27.8	.9924	.3498
Cheatgrass *Bromus tectorum*	44.3 ± 31.5	52.4 ± 32.9	.669	.5071
Fennel-leaved desert parsley *Lomatium foeniculatum*	0.3 ± 1.11	0		
Field chickweed *Cerastium arvense*	0	0.1+1.1		
Longleaved phlox *Phlox longifolia*	2.3 ± 3.8	0		
Bluebunch wheatgrass Seedstalk heights	75.7 ± 7.9	69.2 ± 9.6	2.973	.0039
Shrubs				
Big sageb ush (Artemisia tridentata)				
No. plants	3	0		
Height (cm)	113.3 ± 4.0	0		
No. dead	0	0		
Heath goldenrod (*Ericameria nauseosa)*				
No plants	15	28		
Height (cm)	65.1 ± 18.7	57.6 ± 18.4	1.739	.0951
No. dead	5	14		
Green rabbitbrush (*Ericameria viscidiflorus)*				
No. plants	2	1		
Height (cm)	57 ± 12.7	17	one plant outside	
No. dead	0	2		
Antelope bitterbrush (*Purshia tridentata)*				
No plants	47	3	7.68	.0001
Height (cm)	143.4 ± 42.9	200	.412	.683
No. dead	43	63		

July 1990. The area was on flat ground south of the confluence of Little Loon Creek and the Middle Fork, on a mix of Douglas-fir (*Pseudotsuga menziessia*) /mallow ninebark (*Physocarpus malvaceus*), Douglas-fir/pinegrass (C*alamagrostis rubescens*), and Idaho fescue/bluebunch wheatgrass habitat types (Steele and others 1981).

Herbaceous information was difficult to obtain from equivalent sites inside the exclosed area and adjacent, but no differences were apparent that were attributable to exclusion from grazing. Cheatgrass in the exclosed site was on microsites that appeared to have been severely burned. Similar conclusions applied to the shrub component. Differences were more readily attributable to variation in fire than to exclusion from grazing. The area has served as winter range for elk and deer and was part of a horse allotment when the exclosure was established.

Cow Creek Exclosure Near Loon Creek

This exclosure was still in evidence when examined in July 1992, although the fences were sufficiently down to allow access by mule deer and elk. No evidence of pack stock grazing was apparent on the site. The site was burned in 1954, prior to establishment of the fence in the mid-1960s.

Differences in the herbaceous union in 1992 between the exclosed site and an adjacent comparable site were not substantial (table 8). The most striking differences were the presence of Idaho fescue, more forbs and higher coverage of bluebunch wheatgrass, cheatgrass and Sandberg bluegrass on the exclosed site. Stem densities for the shrub union were slightly lower overall inside the exclosure site than outside, primarily attributable to more mountain sagebrush and rubber rabbitbrush. Big sagebrush and bitterbrush heights were greater on the exclosed site than off. No differences in productivity, in terms of twig density or twig length, were evident in 1992, suggesting that browsing effects were equivalent by that time, even if shrub heights and densities suggested earlier differences when the site was effectively excluded from browsing and grazing.

The site contained bitterbrush/Idaho fescue and antelope bitterbrush/bluebunch wheatgrass habitat types. The combination of past horse, elk and mule deer grazing and browsing had probably altered the vegetation, primarily by reducing the coverage of the forb component, Idaho fescue,

Table 8—Vegetative characteristics of the Cow Creek exclosure site.

Herbaceous species (coverage >5%)	Inside (Canopy cover ± S.D.)	Outside (Canopy cover ± S.D.)	T-test T	T-test P
Bluebunch wheatgress *Pseudoroegneria spicata*	13.3 ± 15.65	7.7 ± 22.86	2.28	.0283
Cheatgrass *Bromus tectorum*	25.5 ± 24.22	20.5 ± 32.13	2.504	.0167
Cutleaf daisy *Erigeron compositus*	0.2 ± 0.59	0		
Green rabbitbrush *Chrysothamnus viscidlflorus*	0.8 ± 3.36	0		
Hoebell's rockcress *Arabis hoelbelli*	0.8 ± 3.36	0		
Idaho fescue *Festuca idahoensis*	0.2 ± 0.59	0		
Lesser spikemoss *Selaginella densa*	3.2 ± 8.82	3.7 ± 14.01	.738	.4649
Longleaf hawksbeard *Crepis acuminata*	0.8 ± 3.36	0		
Sandberg bluegrass *Poa secunda*	7.3 ± 7.25	2.0 ± 4.56	2.652	.0118
Silky lupine *Lupinus sereceus*	5.2 ± 9.42	0		
Silverleaf phacelia *Phacelia hastata*	0	0.1 ± 0.55		
Western gromwell *Lithospermum ruderale*	0.2 ± 0.59	0		
Bluebunch wheatgrass Seedstalk heights	67.6 ± 10.24	71.6 ± 11.1	.941	.3492
Shrubs				
Big sagebrush (*Artemisia tridentata)*				
Density/m^2	.12 ± 1.39	.56 ± .48	1.395	.1707
% decadence	40.0 ± 14.7	12.1 ± 23.5	4.39	.0023
Height (cm)	207.3 ± 181.5	159.7 ± 136.8	0.376	.7099
Twig density/m^2	12.4 ± 13.1	13.2 ± 20.9	1.93	.0611
Twig length (cm)	13.8 ± 5.8	13.7 ± 4.8	2.39	.0276
Heath goldenrod (*Ericameria nauseosa)*				
Density/m^2	.05 ± .34	.14 ± .34	.499	.6202
% decadence	20 ± 26.5	22.9 ± 29.8	.100	.9254
Height (cm)	66.4 ± 22.3	45.4 ± 28.5	.51	.613
Twig density/m^2	6.2 ± 15.4	3.8 ± 7.3	.64	.5279
Twig length (cm)	5.4 ± 1.1	4.6 ± 1.2	3.24	.0021
Antelope bitterbrush (*Purshia tridentata)*				
Density/m^2	.12 ± .11	.06 ± .14	.406	.6867
% decadence	29.4 ± 13.2	51.9 ± 17.8	3.154	.0129
Height (cm)	115.2 ± 43.4	78.3 ± 22.8	2.32	.0400
Twig density/m^2	13.1 ± 22.5	9.3 ± 16.2	.043	.9659
Twig length (cm)	11.8 ± 3.8	12.4 ± 3.2	1.18	.2427

and by keeping shrubs at lower heights. Evidence of alteration from grazing and browsing was judged to be more apparent than evidence from the fire of 40 years earlier, but evidence of both will undoubtedly disappear if the originally enclosed site remains accessible to native ungulates.

Pence Report

This report is a sequence of photographs taken by Thomas Pence, Mackay, Idaho, in October 1925, and by Dan T. Pence, Salmon National Forest, in December 1968. The area covered included Brush Creek to Short Creek on the west side of the Middle Fork River in the vicinity of the "Flying B" and Bernard Guard Station. These sites were found again in June 1988 and rephotographed. The original typewritten report, written by Dan Pence, forester at Cobalt Ranger District, was on file at the supervisor's office, Salmon National Forest, and the report and current photographs are on file with the current author.

Four sites with repeated photographs suggest decreases in antelope bitterbrush and increases in heath goldenrod from 1925 to 1968, with both species appearing to decline subsequently through 1988. Photographs suggested that both species had declined on this site in the intervening 20 years.

The 1968 Pence report stated that the Wilson brothers owned the Mormon Ranch and the "Flying B" property in 1925. The brothers wintered cattle and horses in the area. The Wilsons were reported to have lost up to 500 head of cattle during the 1928 winter, a severe one in this area, after which they sold these properties.

Thomas Pence reported that deer were abundant in 1925 but less abundant in 1968. He felt there was less antelope bitterbrush in 1968 than in 1925 and less grass cover.

Discussion

Much shrub-steppe vegetation on the Middle Fork Salmon River drainage has been undergoing a transition from past disturbance. The areas have a relatively long history of use by humans and their associated livestock, so it should not be surprising that the vegetation has been modified. The area around the "Flying B" was known to serve as a winter range for up to 1,200 head of pack stock that supplied mining operations in the adjacent higher country. Farming was practised at these inholdings, and the associated livestock were no doubt left to graze the adjacent rangelands without much thought being given to effects on the vegetation.

Parts or all of some exclosures did not appear to be within antelope bitterbrush-dominated habitat types but were seral communities of which antelope bitterbrush was a part. The exclosures above the "Flying B" and at Cave Creek appear to represent this condition. These exclosures were established essentially to demonstrate the adverse effects that game, mainly mule deer, were having on antelope bitterbrush and other vegetation, or were established to help judge the effect that livestock grazing was having. Some 40 years after their establishment, there were considerable changes within exclosures, notably that the antelope bitterbrush plants were quite decadent; shifts in plant composition in the understory were also readily apparent. The exclosures were established not long after livestock grazing was reduced in the areas, and they originally excluded vegetation that reflected the effects of this kind of grazing pressure, plus the grazing pressure of the high mule deer populations of the time. The suspicion is that these high mule deer populations were basically attributable to alterations in the shrub complex by the earlier livestock grazing. This type of grazing would likely have favored invasion of big sagebrush, heath goldenrod and bitterbrush onto sites adjacent to sites occupied before the advent of livestock in the area; it would also have favored increases of these shrubs at the expense of the more palatable grasses and forbs on sites formerly occupied as well. An alternative explanation implicating fire suppression along with grazing in enhancing shrub communities was also tenable, but this assumes that fire suppression was effective in the 1910s and 1920s. Now shrubs are becoming decadent over thrifty stands of grass in the exclosures and there are shifts in the understory composition from species like cheatgrass and needle-and-thread to bluebunch wheatgrass and the associated forbs. Mule deer are still common but populations are lower than earlier years, and it is significant that the elk population has increased. The apparent transition from shrubs to grass will probably favor elk over mule deer. Current fire management policies should enhance that transition.

Thus, major habitat change attributable to the varying kinds of grazing pressures in this area over the years is hypothesized to be the major precursor to changes in big game populations, rather than the big game being the major cause of vegetation change. This represents a working hypothesis that may be explored further. The exclosures serve as a valuable guide to plant succession, and the task now is to examine potential reasons for the observed vegetation differences.

Finally, climatic change, including the major drought of the 1930s, quite likely substantially affected these plant communities. Shrubs would be expected to proliferate during those conditions, both on sites where individual species may exist as seral dominants or codominants and on sites where they occur in the climax. During periods of high moisture, the associated bunchgrasses would be favored. Thus, vegetation change would occur in response to natural climatic fluctuation in the absence of human interference, especially since fire frequencies are also affected by these climatic changes. When climate predisposed higher fire frequencies, the combined effects would be reflected in vegetation condition. The fluctuating climate predisposes change in the vegetation complex and, subsequently, the animal complex, that should not be replicated in the future (Holling and Meffe 1996). This contrasts with the concept that change occurs as a long-term cyclic pattern, with conditions repeated at an as-yet undefined long-term interval. These nonforested communities appear to be sensitive to moisture changes and may demonstrate changes through relatively short time periods. in comparison with other less sensitive communities; they are worthy of consideration for long-term monitoring. This is especially true because of the record already available for them. First, however, we should establish the causes of their current condition.

There are conflicting trends in shrub-steppe species composition across the Western rangelands. Burkhardt and Tisdale 1976), Gruell (1983), Hull and Hull (1975), Johnson (1986), Madany and West (1983), Martin and Turner (1977), Passey and Hugie (1962), Tisdale and others (1965) and Vale (1975) suggest that woody species, including the sagebrushes, have increased over this century, in some cases because of grazing, in other cases due to fire suppression, and in others where neither grazing nor fire were important. Grazing and fire prevention are generally held responsible for changes in plant composition in forest and shrub-steppe across the arid West (Gruell 1983, Branson 1985). More recently, evidence has appeared that the increasingly higher concentrations of atmospheric carbon dioxide will alter community composition and function (Bazzaz 1990), with much uncertainty about results (Idso 1998, Vitousek 1994, Strain 1969, Marshall and Zyhang 1994). However, Polley (1997) reported that transition zones between grasslands and forest may be among the first areas to experience species change as CO_2 rises or climate changes, and that trees and shrubs may increase at the expense of grasses.

There is also evidence of long-term increases in the herbaceous components in shrub-steppe (Yeo and others 1990, Austin and Urness 1998). These changes were attributed to changes in livestock and native ungulate grazing, deliberate efforts to reduce or eradicate woody plants to favor herbaceous forages for livestock, and prescribed burns and wildfires that favored herbaceous species over woody species.

If fire suppression and livestock grazing have been the major human influences on these communities, current policy that eliminates or dramatically reduces these influences provides substantial opportunity to investigate systems to detect natural change or climate-induced change, as well as changes related to the effects of rising atmospheric CO_2 as this affects photosynthesis, respiration and plant growth. Lindroth and others (1993) reported that elevated CO_2 atmospheres predicted for the next century will produce measurable changes in individual plant species and affect community structure and nutrient cycling on a broad level. Polley (1997) reported that transition zones between grasslands and forest may be among the initial areas experiencing species change as CO_2 rises or climate changes, and trees and shrubs may increase at the expense of grasses.

These changes may ultimately be related to changes in fauna. Among the herbivorous species, Post and others (1997) concluded that recent trends of increasingly warm winters in northern Europe and Scandinavia would lead to reduced body size and fecundity of red deer (*Cervus elaphus*). If this is an indication of how global warming could affect ungulates, interactions between predator and prey, as well as between prey and forage, may also be affected. The opportunity to assess trends in plant and animal communities in a large, relatively intact ecosystem where other human intrusion is minimized could materially help understanding of the effects of global changes in the northern Rocky Mountains.

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References

Austin, D.D. and P.J. Urness. 1998. Vegetal change on a northern Utah foothill range in the absence of livestock grazing between 1948 and 1982. Great Basin Naturalist 58:188-191.

Bazzaz, F.A. 1990. The response of natural ecosystems to the rising global CO_2 levels. Ann. Rev. Ecol. Syst. 21: 167-196.

Branson, F.A. 1985. Vegetation changes on western rangelands. Range. Monograph 2. 76pp. Society of Range Management, Denver.

Burkhardt, J.W. and E.W.Tisdale.1976. Causes of juniper invation in southwestern Idaho. Ecology 57:472-484.

Daubenmire, R. 1959. A canopy coverage method for vegetation analysis. Northwest Science 33: 43-64.

Gruell, G.E. 1983. Fire and vegetative trends in the northern Rockies: interpretations from 1871-1982 photographs. USDA For. Serv. Gen. Tech. Rep. INT 158. 117 pp.

Hamilton, B. 1990. Challis National Forest, personal communication.

Hartung, J.W. 1978. Documentation of historical resources in the Idaho Primitive Area, Big Creek drainage. M.S. Thesis, Univ. Idaho, Moscow. 161pp.

Hironaka, M., M.A. Fosberg, and A.N. Winward. 1983. Sagebrush grass habitat types in southern Idaho. Univ. Idaho Forest, Wildlife, and Range Expt. Sta. Bull. 35. 44pp.

Hitchcock, C.L. and A. Cronquist. 1973. Flora of the Pacific northwest. University of Washington Press Seattle. 730 pp.

Holling, C.S. and G.K. Meffe. 1996. Command and control and the pathology of natural resource management. Conservation Biology 10: 328-337.

Hull, A.C. and M.K. Hull. 1974. Presettlement vegetation of Cache Valley, Utah and Idaho. J. Range Manage. 27: 27-59.

Idso, S.B. 1998. CO_2-induced global warming: a skeptic's view of potential climate change. Climate Research 10: 69-82.

Johnson, K.L. 1986. Sagebrush over time: a photographic study of rangeland change. In E.D. McArthur and B.L. Welch, compilers. Proceedings-symposium on the biology of *Artemisia* and *Chrysothamnus*. USDA For. Serv. Gen. Tech. Rep. INT-200. Pp223-252.

Lindroth, R.L., K.K. Kinney, and C.L. Platz. 1993. Responses of deciduous trees to elevated atmospheric CO2: productivity, phytochemistry, and insect performance. Ecology 74: 763-777.

Madany,M.H. and N.E. West. 1983. Livestock grazing-fire regime interactions within montane forests of Zion National Park, Utah. Ecology 64: 661-667.

Marshall, J.D. and J. Zhang. 1994. Carbon isotope discrimination and water use efficiency in native plants of the north-central Rockies. Ecology 75: 1887-1895.

Martin, S.C. and R.M. Turner. 1977. Vegetation change in the Sonoran Desert region, Arizona and Sonora. J. Ariz. Acad. Sci. 12: 59-69.

Mueggler, W.F. and W.L. Stewart. 1980. Grassland and shrubland habitat types in western Montana. USDA Forest Serv. Gen. Tech. Bull INT-66. 154 pp.

Passey H.B. and V.K. Hugie. 1962. Sagebrush on relict ranges in the Snake River plains and northern Great Basin. J. Range. Manage. 15: 273-278.

Polley,H.W. 1997. Implications of rising atmospheric carbon dioxide concentration for rangelands. J. Range Manage. 50:561-577.

Post, E, N.C. Stenseth, R. Langvatn, and J-M. Fromentin. 1997. Global climate change and phenotypic variation among red deer cohorts. Proc. Royal Soc. London B 264: 1317-1324.

Scott, M. 1999. Idaho Department of Fish & Game. Personal communication.

Steele, R, R.D. Pfister, R.A. Ryker, and J.A. Kittams. 1981. Forest habitat types of central Idaho. USDA Forest Service Gen. Tech. Rep. INT-114. 138 pp.

Strain, B.R. 1969. Seasonal adaptations in photosynthesis and respiration in four desert shrubs growing *in situ*. Ecology 50: 511-513.

Tisdale, E.W., M. Hironaka, and M.A. Fosberg. 1965. An area of pristine vegetation in the Craters of the Moon National Monument, Idaho. Ecology 46: 349-352.

Vale, T. R. 1975. Presettlement vegetation in the sagebrush grass area of the intermountain west. Jour. Range Management 28: 32-36.

Vitousek.P.M. 1994. Beyond global warming: ecology and global change. Ecology 75: 1861-1876.

Wellner, C.A. 1970. Fire history in the northern Rocky Mountains. In: The Role of Fire in the Intermountain West. Intermountain Fire Research Council Proceedings. Pp 42-64.

Yeo, J.J., W.T. Wittinger, and J.M. Peek. 1990. Vegetation changes on a rest-rotation grazing system. Rangelands 12: 220-225.

Edge Effects and the Effective Size of Old-Growth Coast Redwood Preserves

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Abstract—Data were collected to determine the depth of influence of conditions created by clear-cut timber harvest on adjacent old-growth stands of coast redwood. Fourteen variables related to stand structure and composition, wildlife habitat, and physical environment exhibited significant correlation to distance from the timber harvest boundary. Results were applied to the core area model (Laurence and Yensen 1991) to determine the effective size of forest preserves, and to make recommendations on the size and function of buffer zones. The core area model was used to determine the effective size of the five old-growth patches associated with the study sites. A significant loss in total preserve area due to the presence of induced edges occurred in all cases.

Timber harvesting can affect adjacent forest stands by altering microclimate along the edge of the disturbance and by exposing trees to the dangers of windthrow and crown dieback. These impacts may, in turn, affect vegetation composition and structure. The character of the remaining forest is altered along its edge, reducing the effective size of a preserve (Schonewald-Cox and Bayless 1986). An understanding of the extent to which edge effects reduce the effective size of old-growth forest stands is essential to the proper management of forests, the design of preserves and the implementation of buffer zones.

The removal of canopy cover through clear-cut timber harvesting has been so prevalent in the coast redwood forest type that very little of the original forest remains. Virtually all of the remaining old-growth forest is preserved on public lands. In most cases, these preserves are surrounded by managed land. The boundary between the preserved forest and managed areas is not static. Biotic and abiotic factors within managed areas can alter characteristics of adjacent stands. The interface between the two communities (managed and preserved) is referred to as the edge and is distinct in terms of composition and structure.

Physical and biological factors that actively move material or energy across landscape boundaries have been referred to as vectors (Kelly and Rotenberry 1996). Kelly and Rotenberry describe a method for designing buffer zones that requires the identification and ranking of present vectors. Potential vectors can be inhibited by reducing boundary permeability. This can be accomplished through a variety of means, including increasing the size of buffer zones, or altering the type of activities permitted within buffer zones. Discussions about impacts of edge effects on the integrity of preserves can focus on the vectors themselves, or on the measurable impact of these vectors on biotic variables.

A discussion of effective old-growth size by Harris (1984) focused on a single vector. Heightened wind effects could be measured for a distance of approximately two to three tree heights into old-growth stands. Harris suggests that the distance of edge influence could be based on a "three tree height" rule of thumb. Further, he suggests that since most old-growth islands have irregular shapes the "three tree height" rule is inadequate. He suggests that six tree heights would give a more accurate measure of the edge influence for preserves with irregular shapes. Harris also discusses the importance of the matrix in which an old-growth island exists. Effective size of old-growth preserves can be increased if the preserve is surrounded by late seral second-growth stands.

The importance of matrix is discussed further in Janzen's (1983) inestigation of a forest preserve in Costa Rica. Janzen focused on a single biotic variable, species composition, for his analysis. He suggests that the integrity of residual pristine forest may be better preserved if the residual forest is surrounded by managed lands, such as monoculture agricultural systems, rather than second-growth forest. He argues that exotic species are more likely to invade from species-rich regenerating forest, while the unsuitability of most agricultural plants to forest interior conditions makes their invasion unlikely. His analysis is limited, however, by his single variable approach. Variables other than species composition may also be impacted by adjacent agriculture. The single-variable approach is effective only when managing specifically for that variable. It is not necessarily the most useful approach in determining the effective size of preserves.

A multiple-variable approach was used to determine the influence of edge on the effective size of preserves (Franklin and Foreman 1987). Franklin and Foreman suggest that the total edge within a landscape unit should be minimized in order to protect "interior species and amenity values" of residual old-growth patches. These conclusions were reached by applying a simple geometric model of timber harvest configurations to a hypothetical landscape. The effect of harvest patterns was analyzed in terms of potentials for disturbance, such as blowdown and landslide, and biotic

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factors such as species diversity. These factors were shown to be correlated to distance from the edge. For example, species diversity was shown to decrease in proximity to the edge.

A model for determining the core area, or the effective size, of a preserve was developed by Laurence and Yensen (1991). This model refines portions of an earlier model developed by Patton (1975). Laurence and Yensen's model used two factors to predict core area. A shape index term was combined with edge function (the depth of the edge influence of an unspecified variable or variables) to determine the affected area. The affected area was then subtracted from the total area to determine the core area. Applying this model to tropical forest fragments in Australia, Lawrence (1991) plotted the relationship of several variables with distance from the edge. The variables that exhibited the greatest depth of edge influence were selected for use in the model. This model is useful in comparing the relative edge effect on preserves with different shapes and can easily be adapted to a multivariable approach.

Similar results were determined using a GIS model to automate the same functions carried out by the core area model (Ripple et al. 1991). The precise area of influence was readily defined and calculated. However, the developers of this approach did not address the question of what variables should be used to measure depth of edge influence. For the purpose of the paper, a conservative two tree height rule was used, and the depth of influence was set at 100 meters. A multivariable approach could be applied to this method in a manner similar to the core area model.

In general, these models suggest that the greater the length of the perimeter, in relation to the area of the preserve, the smaller the core area will be. Therefore, in order to maximize the integrity of an old-growth stand, the perimeter/area ratio should be as small as possible. Application of the theory of island biogeography (MacArthur and Wilson 1967) on isolated preserves suggested a circular shaped preserve with the largest possible area offered the best chance of preserving biodiversity (Diamond 1975).

A contrary management strategy advises that the perimeter/area ratio of preserves should be maximized (Brown 1985). This management option was supported by research that suggests that species richness and habitat diversity increase in proximity to the edge (Beedy 1981, Gates and Gysel 1978, Hanley 1983). In addition, the validity of applying the theory of island biogeography to ecological rather than oceanic islands has been questioned, particularly in regard to the emigration of species (Janzen 1983). It is significant that the research cited to support this management option is generally related to wildlife diversity (Harris 1988). Also, the research which shows that species diversity has been elevated in proximity to community boundaries has often been conducted on natural, or long-term induced, edges. Results for the diversity of plant species on temporary induced edges has generally yielded inverse results (Burgess and Sharpe 1981).

The question of minimizing versus maximizing edge is really a question of what variables are measured and what factors are being managed for. There is strong evidence that management for increased edge does allow the proliferation of certain wildlife species, especially game species (Brown 1985). In contrast, management for decreased edge helps preserve the intrinsic characteristics of residual stands, including vegetation composition and structure, and the complement of wildlife species dependent on the conditions of the forest interior. For example, a species such as the spotted owl requires a minimum area of old-growth forest to persist. Unfortunately, these characteristics have not been well defined in the literature. It is much more complex to manage for an entire community or forest type than it is to manage for a single species. However, if the management goal is to preserve the intrinsic characteristics of a stand, including its structure and composition, the best approach is to measure as many related variables as possible in order to determine the effect of edge on each.

The goal of this study was to determine the effects of clear-cut timber harvesting on the structure and composition of adjacent old-growth coast redwood (*Sequoia sempervirens*) forest. A wide variety of variables related to species diversity and occurrence, development of understory and overstory species, wind damage to exposed trees, effects on wildlife habitat, and abiotic factors were measured to determine the depth of edge influence, to estimate the effective size of old-growth redwood preserves and to make recommendations in regard to buffer zones in this forest type.

Methods

Data were collected along 360 meter transectsrandomly located across the boundaries between clear-cut areas and adjacent old-growth stands on nine sites in the redwood forest region of northern California. A stepwise regression analysis of this data was used to identify the depth of influence of the clear-cut areas on the old-growth forests. Effective size of preserves was then predicted on the basis of the depth of influence of measured variables, with the core area model.

Site Characteristics

Nine sites were sampled within the Redwood National and State Parks management area in Northern California (table 1). Sites were located where a distinct boundary separated harvested and old-growth stands. An effort was made to choose sites where the old-growth components were as similar as possible in terms of structure and composition. Three sites were selected in each of three post-harvest age groups (20, 30, and 50 years since harvest) in order to illustrate effects of time on the composition and structure of vegetation.

Sampling Strategy

Ten transects were randomly located on each site, perpendicular to the boundary of the timber harvest (defined as the point where no cut stumps were visible). Circular 20-meter diameter sample plots were set at 40-meter intervals along transects, with five plots on each transect located within the uncut forest and four plots located in the regenerating stands. The data collected on sample plots were used to quantify the following variables:

Table 1—Characteristics of study sites.

Name of study site	Year of harvest	Elevation (meters)	Average slope (%)	Aspect	Harvest area (he)	Orientation of cut
Emerald Creek	1974	120-180	37.6	SE	17.6	NW
Dedication Grove	1972	120-180	23.7	SE	65.8	NW
Tall Trees	1973	150-215	28.6	SW	17.6	E
Lady Bird Johnson	1964	180-240	21.7	NW	70,1	NW
Lady Bird Johnson	1965	180-240	34.2	NW	8.78	N
Walker Road	1966	75-180	36.1	E	34.4	N
Liefler Loop	1948	75-180	33.5	E	17.4	N
Wilson Creek	1948	180-240	32.9	NE	44.5	N
Lady Bird Johnson	1945	240-300	38.3	S	101.0	S

- Height of canopy layers (canopy, subcanopy, shrub, herb)
- Frequency of observed crown die-back
- Percent cover and cover class of canopy layers
- Density of size classes and density of size classes by species
- Dominance of major tree species
- Frequency of all species occurring on sample plots

Variables were selected for further analysis based on their correlation to distance from the timber harvest boundary, using a standardized z-test. Variables with a p-value of 0.05 or less were used, except in cases of covariance. Where a correlation coefficient greater that 0.5 was found for two variables, the variable with the highest p-value was removed.

Determining the Depth of Influence

Variables that were determined to be highly correlated to distance from the boundary were plotted on a linear scale. A third order polynomial curve was applied to the distribution of each variable. This curve was then analyzed using a procedure adapted from Oosting (1948). For this procedure, a ratio of the x and y axes was used to determine the angle of a tangent line. The point where this tangent line intersected the curve was the confidence point for depth of influence. For the greatest accuracy, Oosting suggests a ratio of 5% rise to 10% run. The tangent point then indicates where a 5% increase in the value of the sample variable occurs over 10 % of the distance of the transect. Less than a 5% slope is therefore assumed to be zero. This results in a conservative estimate for the depth of influence, thereby increasing the confidence in that estimate.

Application of the Core Area Model

Estimations of the depth of influence were applied to the core area model, as described by Laurence and Yensen (1991). This model uses two factors to predict core area of forest patches, assuming they are completely surrounded by harvested land. The edge function describes the distance of edge influence into a stand. The shape index describes the perimeter to size ratio of a site.

The shape index (SI) describes the deviation of the shape of a preserve from a circle. A circle that has the lowest possible area to perimeter ratio is given an SI of 1. The shape index was calculated using the total area (TA) and the perimeter length (P).

$$SI = \frac{P}{200\left[(\pi TA)^{0.5}\right]}$$

The shape index term was combined with an edge function (d) "depth of influence" to determine the affected area (AA).

$$AA = \{(3.55)(d)(SI)[(TA/10{,}000)^{0.5}]\}$$

The affected area was then subtracted from the total area TA to determine the core area.

Core Area = TA-AA.

Buffer Zones

The depth of influence calculated for the study sites was compared to the "three tree height rule" (Harris 1984). Appropriate buffer zone width was then estimated using both the "three tree height rule" and the depth of influence estimate from the data gathered in this study.

Results

A total of 13 variables were found to have significant correlation to distance from the timber harvest boundary (table 2). Correlation coefficients and p-values were determined separately for each of the post-harvest age groups, in order to compare the effects of time on these variables. The sign of correlation coefficients describes the slope of the line from the timber harvest boundary into the uncut forest. A positive slope, therefore, indicates a negative impact on that variable in proximity to the edge.

In addition to correlation factors, the depth of influence was calculated for each variable. A wide range of influence was exhibited by the sample variables (0 to >200 meters). Solar radiation, for example, exhibited a positive correlation with distance from the edge out to approximately 180 meters within the old-growth portion of the stands (fig. 1). The distribution of this variable is of particular significance because solar radiation is a vector of influence. Therefore, the distribution of other variables can be discussed in relation to this variable.

Table 2—Depth of influence of variables correlated to distance from the timber harvest boundary.

Variable		Correlation coefficient	P-value	Depth of influence (meters)
Sub-canopy height		0.341	< 0.0001	> 200
	20 yr.	0.559	<0.0001	> 200
	30 yr.	0.497	<0.0001	> 200
	50 yr.	-0.077	0.4014	n/a
Solar radiation		0.339	< 0.0001	180
	20 yr.	0.415	< 0.0001	140
	30 yr.	0.376	< 0.0001	>200
	50 yr.	0.776	< 0.0001	n/a
Sub-canopy cover		- 0.314	< 0.0001	160
	20 yr.	- 0.245	0.0068	> 200
	30 yr.	-0.100	0.2767	120
	50 yr.	- 0.649	< 0.0001	120
Pole density		- 0.229	< 0.0001	80
	20 yr.	-0.422	<0.0001	120
	30 yr.	-0.413	<0.0001	40
	50 yr.	0.117	0.2053	0
Crown dieback		- 0.217	< 0.0001	120
	20 yr.	0.249	0.0059	80
	30 yr.	0.219	0.0159	120
	50 yr.	0.242	0.0075	120
Richness of shrubs		0.213	< 0.0001	40
	20 yr.	0.133	0.1468	40
	30 yr.	0.405	< 0.0001	40
	50 yr.	0.129	0.1590	n/a
Herbaceous cover		0.208	< 0.0001	120
	20 yr.	- 0.319	0.0004	120
	30 yr.	-0.353	< 0.0001	120
	50 yr.	-0.128	0.1646	160
Species Richness		0.169	0.0013	180
	20 yr.	0.106	0.249	160
	30 yr.	0.193	<0.0001	160
	50 yr.	0.400	<0.0001	>200
Bear Damage		- 0.141	0.0075	40
	20 yr.	0.153	0.0943	40
	30 yr.	-0.199	0.0294	n/a
	50 yr.	-0.397	<0.0001	n/a
Seedling density		0.139	0.0080	120
	20 yr.	0.176	0.0549	120
	30 yr.	0.157	0.0870	160
	50 yr.	0.176	0.0545	n/a
Density of poles (Red Alder)		- 0.134	0.0108	80
	20 yr.	- 0.235	0.0096	0
	30 yr.	- 0.188	0.0401	40
	50 yr.	0.024	0.7918	80
Dominance (Douglas-fir)		- 0.133	0.0116	40
	20 yr.	- 0.171	0.0622	40
	30 yr.	- 0.256	0.0046	40
	50 yr.	0.063	0.4944	n/a
Richness of trees		- 0.110	0.0377	40
	20 yr.	-0.364	<0.0001	0
	30 yr.	0.019	0.8364	40
	50 yr.	0.025	0.7855	120

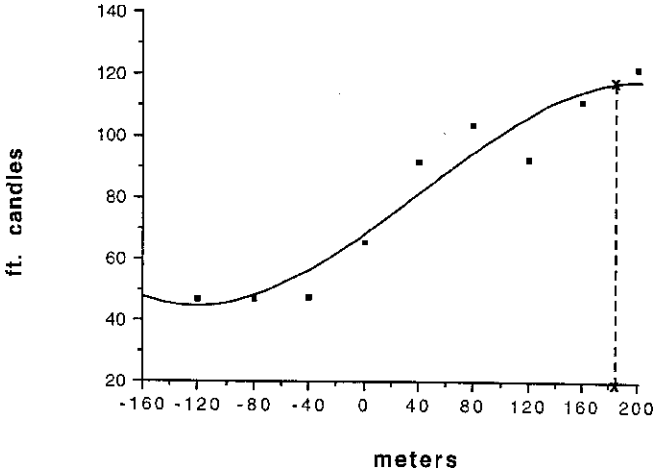

Figure 1—Solar radiation and distance from the edge. The scale on the x axis refers to distance from the edge as positive in the direction of the old-growth forest and negative in the direction of the regenerating areas. The zero mark represents the timber harvest boundary.

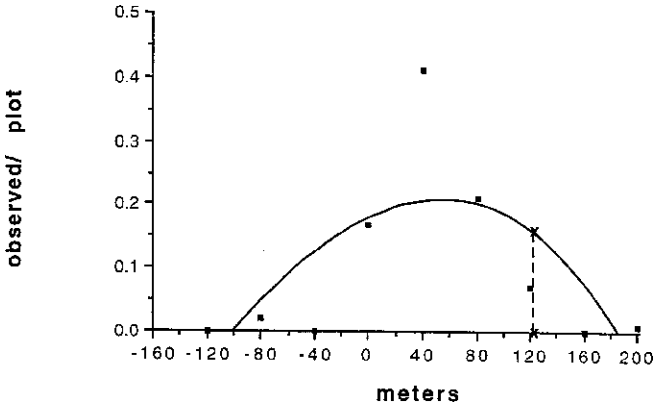

Figure 3—Crown dieback and distance from the edge.

Species richness and solar radiation exhibited nearly identical curves (fig. 2). The depth of influence in this case was also approximated at 180 meters. It is important to note that though the slope of the line is positive, the influence of the edge is negative. Species diversity is reduced in proximity to the timber harvest boundary. The similarity of these two variables was not coincidental. The decrease in species richness in proximity to the edge is likely the result of decreased solar radiation. This argument is supported by a significant correlation between the two variables ($p < 0.0001$).

In contrast to the previously discussed variables, the correlation of crown die-back to distance from the edge was negative (fig. 3). The depth of influence was 120 meters, and the shape of the distribution curve was different from that of species richness. The reason for these differences is most likely related to vectors. In contrast to species richness, which was correlated to lower solar illumination, the frequency of crown die-back was most likely the result of higher wind velocity near the edge.

The correlation of the density of red alder (*Alnus rubra*) poles also exhibited a negative correlation to distance from the edge, indicating a higher density of poles in proximity to the timber harvest boundary (fig. 4). The depth of influence in this case was approximately 80 meters.

The depth of influence of the timber harvest boundary was also related, in many cases, to time since harvest. Notable variation was apparent in the slope and depth of influence of many variables in relation to time since harvest. For example, the relationship between solar radiation and distance from the timber harvest boundary varied considerably between the three post-harvest age groups (fig. 5). The distribution for the 20-year-old age group was characterized by a relatively steep slope and a depth of influence of approximately 140 meters. The slope for the 30-year-old age group was slightly less steep, but the depth of influence was in excess of 200 meters. The 50-year-old age group was characterized by a zero slope, showing no depth of influence.

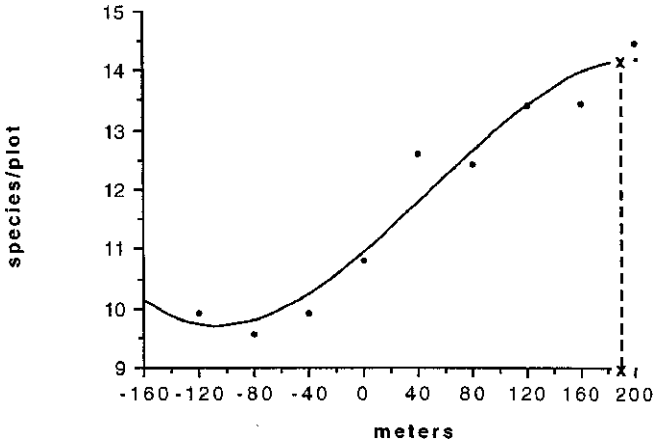

Figure 2—Species richness and distance from the edge.

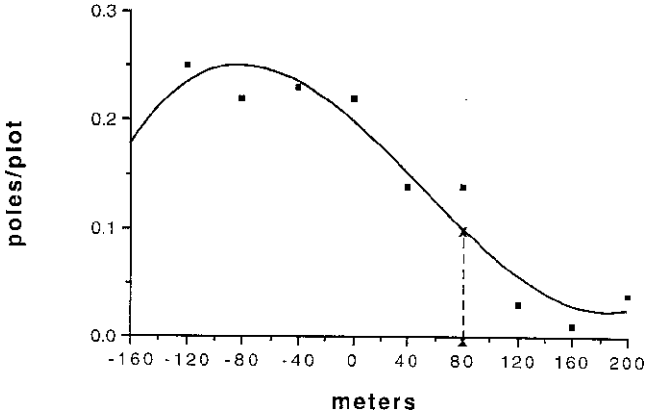

Figure 4—Density of alder poles and distance from the edge.

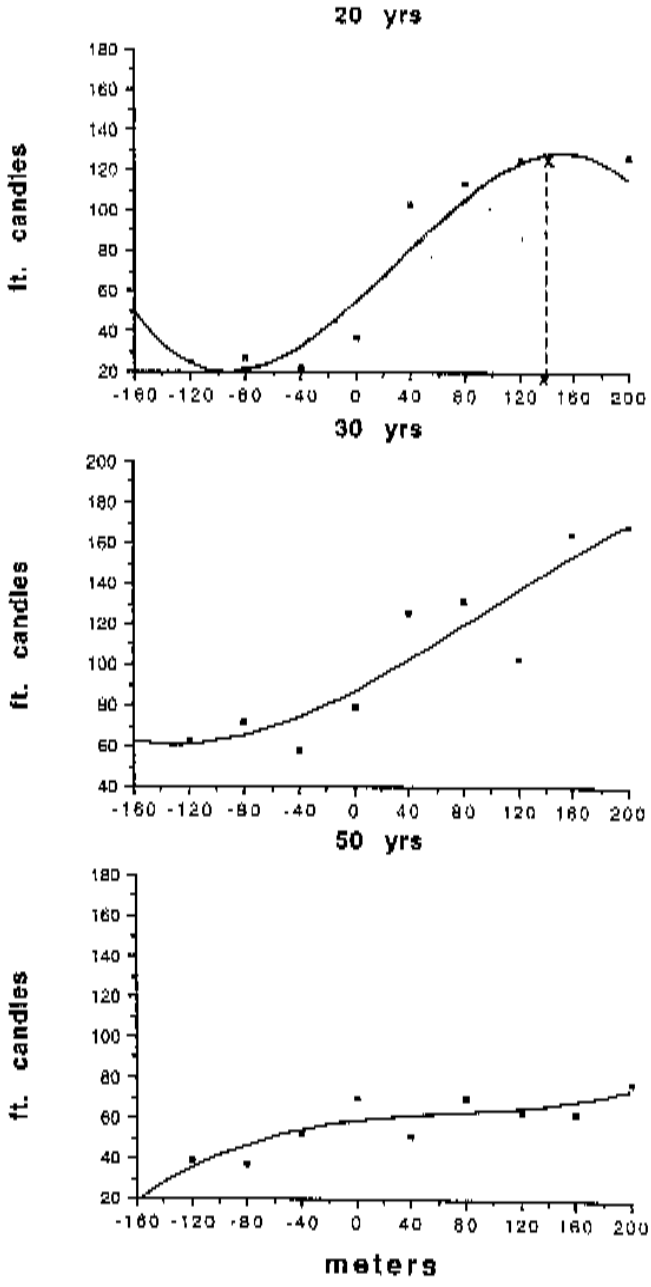

Figure 5—Solar radiation chronosequence.

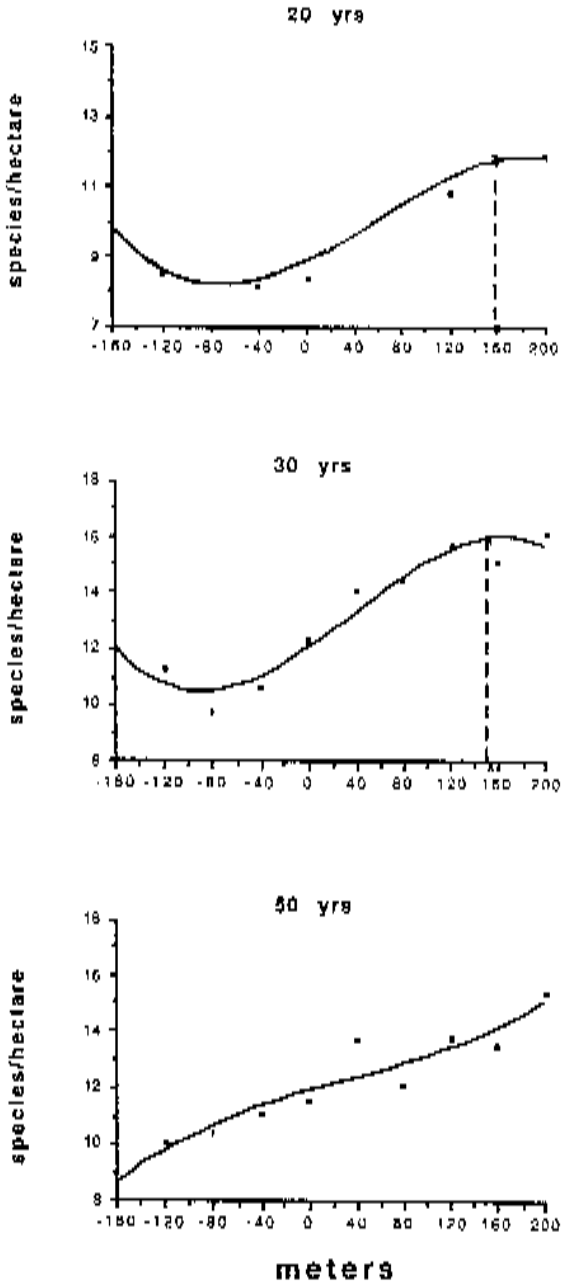

Figure 6—Species richness chronosequence.

An analysis of the three age groups together reveals a pattern of influence for this vector of influence that resembles a wave. Initially the crest is high, but the magnitude of the wave diminishes with time, until it virtually disappears.

A similar pattern was apparent for species richness (fig. 6). However, because variation in species richness was related to variation in solar radiation, the peak magnitude was delayed. The greatest slope was found for the 30-year-old age group, and by 50 years the slope began to erode. In addition, in a similar fashion to solar radiation, the depth of influence increased with time, from 160 to greater than 200 meters.

The distribution of crown dieback frequency also suggested an increase in depth of influence with respect to time (fig. 7). However, because the visible effects of crown dieback persist, there was no leveling of the slope at 50 years.

The clearest example of a time effect was observed for the pole density of alder (fig. 8). As a species that usually occupies open areas or riparian sites, alder is quite rare within undisturbed old-growth redwood forests. Consequently, virtually no alder was found within the old-growth areas sampled for the 20-year-age group. The 30 and 50 year age groups, however, exhibited an elevated density of this species out to 40 meters and 80 meters, respectively. A time effect is also apparent on the harvested side of the timber harvest boundary. Where density of alder is elevated out to -160 meters within the cut-over areas for the 20- and

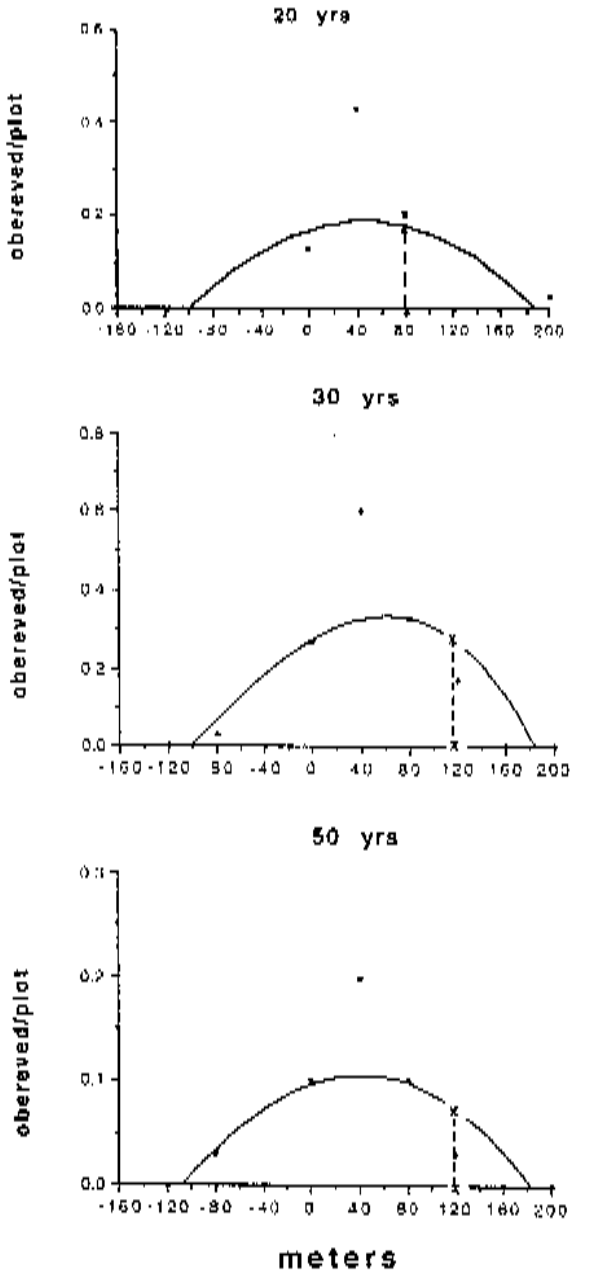

Figure 7—Crown dieback chronosequence.

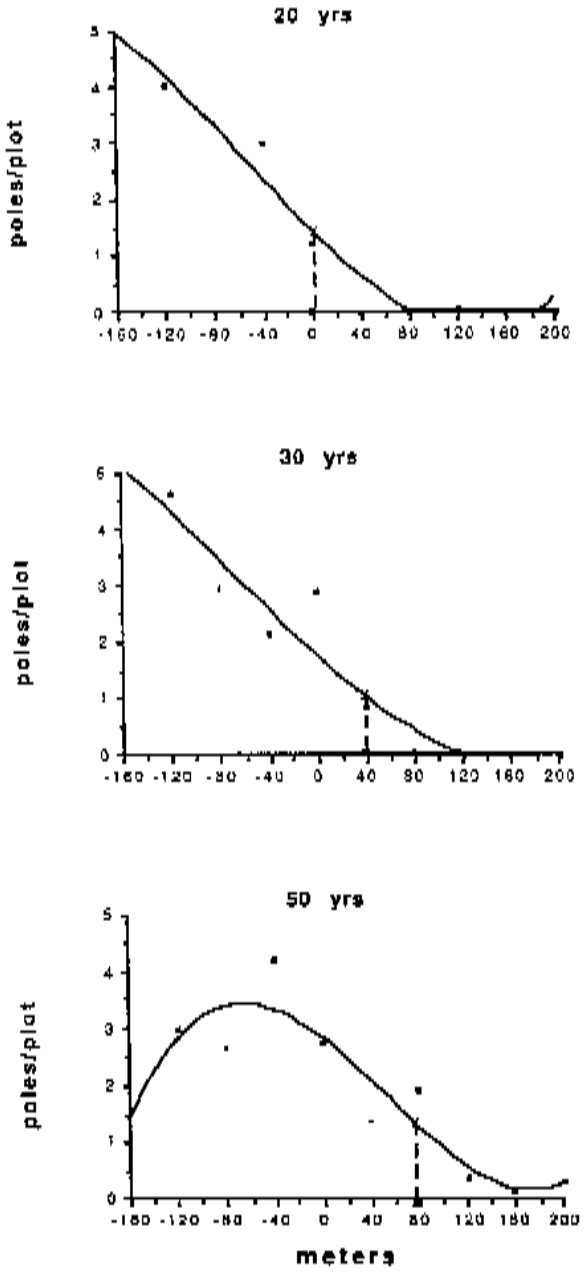

Figure 8—Density of alder pole chronosequence.

30-year-old age groups, the density began to decline beginning at -80 meters in the 50-year-old stands.

The results of this analysis indicate that the depth of edge influence is dependent on the variable in question and that time is a factor in the depth of edge influence. However, it is clear that the edge created by timber harvest significantly influenced the structure and composition of adjacent communities and that this influence, in many cases, was extensive (greater than 200 meters).

Effective size of preserves

The influence of the induced edge created by timber harvest is dependent on the variable measured. A large number of variables were measured in this case in order to gain a broad understanding of edge influence on the intrinsic properties of old-growth redwood forests. A number of variables exhibited a depth of influence in excess of 200 meters suggesting that the intrinsic properties of the residual stands were influenced out to this point. Consequently, 200 meters was used as the standard for the following analysis. If a specific variable were being manage d for the depth of influence for that variable would be used.

Harris Model—The "three tree rule" is supported by the results of this study. The average canopy height at the furthest distance from the timber harvest boundary within the old-growth stands sampled was 60 meters. Using 60 meters as tree height, three times tree height equals

180 meters, which is similar to the 200 meter depth of influence determined by this study.

The Core Area Model—The model developed by Laurence and Yensen (1991), for determining the effective size of preserves, was applied to the old-growth stands associated with each study site, using the 200 meter depth of influence estimated with data from this study. Results from this analysis indicate that a substantial amount of the preserve areas were compromised adjacent to timber harvest operations (table 3).

The size and shape of each preserve were the determining factors in the estimation of the affected areas. Preserves with low shape indexes tended to be less affected, except when the total area was very small. For example, despite a low shape index, the calculated affected area for Dedication Grove was actually greater than its total area, indicating that the entire grove was influenced by the induced edge created by timber harvesting.

For larger preserves, the affect of shape was more apparent. The northern and southern portions of the Redwood Creek drainage included core areas which composed 65% and 32% of their total areas, respectively. This dramatic difference is due primarily to the extremely irregular perimeter of the uncut portion of the southern part of the creek. An intermediate proportion of core area (61 %) was estimated for the Mill Creek, and the highest proportion of core area (68 %) was estimated for the Jedidiah Smith grove due to its nearly square shape.

It is important to note that these estimates are based on the existence of a continuous boundary of harvested land surrounding each preserve. This contingency is presently the case for all of the sites. However, the imposition of Park jurisdiction over much of the previously harvested areas has resulted in a reduction of the disturbance in some cases. The old-growth forest stands along Redwood Creek, for example, are surrounded by lands protected by Redwood National Park. These lands are characterized by regenerating forests, which will mature over time and effectively increase the core area of these preserves.

Conclusions

Results from data collected on nine sites within the Redwood National and State Park management area indicate that induced edges created by timber harvest have significant impacts on the structure and composition of adjacent old-growth coast redwood stands. Application of the core area model (Laurence and Yensen 1991) further suggests that this influence has reduced the effective size of the old-growth stands associated with these study sites. These results have important implications for the preservation of this forest type in regard to the design of preserves and the size of buffer zones. In order to apply these results, however, a clear understanding of management goals must be achieved.

A great deal of variability was found in the depth of influence of induced edges on the measured variables. The importance of the variables chosen for analysis of effective preserve size cannot be understated. A wide range of factors were measured for this study in order to gain a general understanding of edge effects on stand structure and composition. The maximum depth of influence of 200 meters used in this analysis was based on the maximum depth of influence of a number of these variables. If a specific factor is being managed for, rather than general stand integrity, the depth of influence of that factor should be used rather than a generalized measure. In addition, if the management goal is protection of other resources, such as riparian systems, other variables would need to be included.

The validity of using a 200-meter depth of influence is supported by the "three tree height rule" (Harris 1984). With an average canopy height of between 46 and 76 meters at the furthest distance from the timber harvest boundary, the "three tree height rule" suggests a depth of influence of 138 to 228 meters. It is important to note that when applying this rule to preserves with irregular boundaries, Harris suggests the use of a "six tree height rule".

The core area model allows for a more systematic approach to the application of depth of influence estimates to preserves with irregular boundaries. The proportion each of the old-growth stands affected by boundary conditions varied widely and was dependent on the size and shape of preserves. In general, the results of this study suggest that, for stand characteristics such as the composition and structure of vegetation large preserves with a low perimeter to area ratio are the most resistant to edge influence.

Beyond the creation of preserves with appropriate shape and size, buffer zones are the best method for insulating a forest community from outside influences. A buffer zone has two properties, permeability and width. The permeability of a buffer zone is related to the ability of vectors to move through it. Solar radiation was measured as a vector in this study and showed a maximum depth of influence of more than 200 meters. Management activities such as selective harvesting within a buffer zone are likely to increase the permeability for this and other influence vectors. Measurements of the affect of permeability of buffer zones on the depth of edge influence were beyond the scope of this study, but offer excellent opportunity for further inquiry.

Assuming a buffer zone with no harvest activity and a preserve with a regular perimeter, a buffer zone that protects the integrity of the total area of the stand should be

Table 3—Core area model results.

Preserve	P	TA	SI	d	AA	CA
Dedication Grove	4634 m	58 he	1.72	200 m	93 he	0 he
Del Norte	26346 m	991 he	2.76	200 m	617 he	374 he
Jedidiah Smith	42327 m	2994 he	2.44	200 m	948 he	2046 he
Redwood Creek N	74085 m	5189 he	3.55	200 m	1816 he	3373 he
Redwood Creek S	54376 m	1785 he	4.06	200 m	1217 he	567 he

equal in width to the depth of edge influence. The results from this study indicate that for old-growth coast redwood stands this width would be a minimum of 200 meters, or approximately three times the average tree height.

Acknowledgments

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References

Beedy, E. C. 1981. Bird communities and forest structure in the Sierra Nevada of California. Condor 83(2): 97-105.

Brown, E. R., 1985. Edges: Management of wildlife and fish habitats in forests of western Oregon and Washington. USDA Forest Service Pacific Northwest Region.

Burgess, R. L., and J. L. Sharpe. 1981. Forest island dynamics in man-dominated landscapes. New York: Springer-Verlag.

Diamond, J. M. 1975. The island dilemma: Lessons of biogeographic studies for the design of natural preserves.

Franklin, J. J., and R. T. T. Forman. 1987. Creating landscape patterns by forest cutting: Ecological consequences and principles., Landscape Ecology 1: 5-18.

Gates, E. F., and L. W. Gysel. 1978. Avian nest dispersion and fledgling success in field forest ecotones. Ecology 59(5): 871-883.

Hanley, T. A. 1983. Black-tailed deer, elk, and forest edge in a western Cascades watershed. J. Wildl. Manage. 47(1): 237-242.

Harris, L. D. 1984. The fragmented forest: Island biogeography theory an the preservation of biotic diversity. University of Chicago Press, Chicago.

Harris, L. D. 1988. Edge effects and conservation of biotic diversity. Conservation Biology 2(4): 330-339.

Janzen, D. H. 1983. No park is an island: increase in interference from outside as park size decreases. Oikos 41: 402-410.

Kelly, P., and J. Rotenberry. 1996. Buffer zones for ecological reserves in California. *Native Species Network* 3:1-2.

Laurence, W. F. 1991. Edge effects in tropical forest fragments: application of a model for the design of nature preserves.

Laurence, W. F., and E. Yensen. 1991. Predicting the impacts of edge effects in fragmented habitats. *Biological conservation* 55: 77-92.

MacArthur, R. H., and E. O. Wilson. 1967. The theory of island biogeography. Princeton University Press. Princeton New Jersey.

Oosting, H. J. 1948. The study of plant communities: An introduction to plant ecology. W. H. Freeman and Company. San Francisco, California.

Patton, D. R. 1975. A diversity index for quantifying habitat edge. Wildlife Society Bulletin 3(4):171-173.

Ripple, W. J., G. A. Bradshaw, and T. A. Spies. 1991. Measuring forest landscape patterns in the Cascade Range of Oregon, USA. Biological Conservation 57:73-88.

Schonewald-Cox, C. M. and J. W. Bayless. 1986. The boundary model: A geographical analysis of design and conservation of nature preserves. Biological Conservation 38:305-322.

Monitoring Reproduction and Contraception in Free Ranging Wildlife: Tule Elk (*Cervus elaphus nannodes*) at Point Reyes National Seashore

Susan E. Shideler

Abstract—The desire of the public to protect free-ranging animals in environments that are devoid of natural regulators can lead to overabundance of urban wildlife in closed habitats. In some parks and reserves, innovative management plans are needed that will include protocols to determine when and if artificial methods of population control should be applied to free-ranging wildlife as an acceptable alternative to hunting or culling. One management option that soon may be available for wildlife application is contraception. Information important to the development of approved contraception programs includes assessment of reproductive characteristics of the targeted species under changing environmental conditions as well as assessment of contraceptive efficacy. This information will improve the ability to accurately estimate the demographic characteristics of animal populations warranting management intervention as well as an evaluation of the success of interventions.

Overabundance of animals associated with increased urbanization of open spaces is a national problem, occurring with increasing frequency in national parks, reserves, national monuments and on private lands (Hadidian 1993; Tzilkowski and others 1993; Supernaugh 1993). Increased contact between the public and wildlife has sharpened public interest in protecting wildlife in environments now devoid of natural controls. As mentioned above, it has been suggested that the absence of controls can lead to overpopulation, destruction of habitat and, ultimately, the potential for population collapse as susceptibility to disease increases with increased numbers (Mc Collough and others 1993).

In national parks, reserves and private lands that are large enough to support ecological process management, artificial intervention is not needed. Ecological process management, as used here, refers to the management of public lands by allowing ecological processes to occur, including, but not limited to periodic disturbances such as fire, floods, drought, and herbivory, predation, births, deaths, decomposition, nutrient cycling, etc., as described by Boyce (1998). In public lands where such management is not an option, some form of intervention to regulate animal population growth is required. Traditional methods of direct intervention consist of culling, hunting and, where possible, relocation. Indirect intervention, such as the reintroduction of predator species or the removal of available critical resources, is also used. In national parklands like Point Reyes National Seashore (PORE), where much of the land is multiuse, and where an educated and well-funded advocacy constituency is actively involved in all aspects of park management, many of these traditional methods are not acceptable. Frequently, the preferred management option is self-regulation. Most people recognize, however, that self-regulation is not likely where natural regulators have been removed. One approach to animal population control that appeals to the public and which may have use for management is wildlife contraception.

Recent developments in noncapture field methods have improved our ability to contracept wildlife and to evaluate efficacy by monitoring reproductive physiologic patterns in free-ranging wildlife. Current sampling methods decrease risks to animals and researchers, reduce the difficulties of sample collection and storage and increase the amount of sample available for analyses (Kirkpatrick and others 1996b). Specifically, developments in urinary and fecal hormone assay techniques have provided the additional advantage of making it possible to use samples that are adaptable to many different assay formats. This adaptability of the sample to various assay formats allows assay systems to maximize the high hormone concentrations found in excreta and to obtain integrated hormone measures reflecting current reproductive status, as opposed to acute reactions to the stresses of capture and venipuncture. The work presented here uses fecal ovarian steroid monitoring of reproduction to evaluate contraceptive efficacy in free-ranging wildlife, using the California native tule elk (*Cervus elaphus nannodes*) as an example.

The tule elk is a native California deer subspecies that ranged in the hundreds of thousands throughout the state prior to the mid-1800s. By 1873, over-exploitation, habitat reduction and disease reduced their numbers to the point of near extinction. At that time tule elk were accorded full protection under California State law. As a protected species, elk numbers increased from five to ten remaining elk in Kern County, California, to approximately 145 by 1905 (Mc Cullough 1969). From this core group of animals, herds were established in Colusa County and in Owens Valley. In 1974, the California Department of Fish and Game (CDFG) and PORE agreed to begin the reintroduction of the tule elk to a suitable range on the seashore. The physical translocation of 10 elk from the San Louis National Wildlife Refuge to Point Reyes took place in 1978 (Gogan 1986) as part of the CDFG's conservation program and in response to the National Park Service's mandate to restore extirpated forms of wildlife to their historic former ranges. The Tule

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Elk Range at PORE is a 1,050 hectare enclosed area, a former dairy cattle range, located on Tomales Point at the north end of Point Reyes Peninsula in Marin County. On the eastern side of the point are Tomales Bay and the San Andreas Fault Zone, to the west, the Pacific Ocean. The weather is a temperate marine climate with moderate winters, some rain and warm, dry summers, with fog along the coast.

Since the initial introduction in 1978, the elk have reproduced without unnatural restriction. While the population growth rate was slow over the first 12 years, it has steadily increased over the last five years. An initial carrying capacity of between 140 and 350 animals was estimated for this recovering habitat in 1986 (Gogan 1986). As of 1997, 465 tule elk were on the Tomales Point Elk Range. A revised, more recently established carrying capacity for the elk range was set at 330 (Bartolome 1993). Currently, in 1999, there are approximately 552 elk on the Tomales Point Elk Range, with an anticipated 70-100 calves due prior to the 1999 rutting season. It is uncertain whether this current growth rate, if sustained, will precipitate the degradation of the habitat or have other negative impacts on sensitive plant and animal species also located on the Tomales Point Elk Range, as suggested earlier (Mc Collough and others 1993).

In the mild habitat of the Tomales Point Elk Range where most natural regulators have been removed—with year-round food and water availability, no possible dispersion or emigration and no large predator populations—there is an apparent need for management to slow the rate of increase of elk to prevent overpopulation. In this study, we tested the efficacy of the double shot pZP vaccine in the tule elk. This vaccine is administered once by hand-injection to elk cows at the time of capture and radio collaring and by giving a remote booster shoot by dart gun three to five weeks later. The principal objective of this study was to assist PORE in assessing its options for elk population control by developing the technology to predict realized reproductive output and to control increases in population numbers in a closed habitat. Fecal ovarian steroid hormones were monitored to assess the reproductive condition of untreated and treated elk cows and to monitor the efficacy of the contraceptive agent in cows treated with the immuno-contraceptive "pZP" (porcine zona pellucida).

Materials and Methods

Field Methods

Sixty-four radio-collared adult elk cows were included in this study. Twenty-nine of these cows were treated with pZP vaccine (obtained through the Humane Society of the United States; manufactured by the laboratory of Dr. Irwin Liu, Department of Population Health and Reproduction, School of Veterinary Medicine, University of California, Davis, California) to inhibit reproduction in early July of 1997. An initial injection of emulsified immunogen (500ul of 135ug pZP in 500ul Freund's Complete Adjuvant™) was administered by hand at the time of capture and collaring. Three to five weeks later, in August, these same cows were given a booster shot (500ul of 135ug pZP emulsified in 500ul Freund's Incomplete Adjuvant™) by remotely delivered darts, using a Model 193 cartridge-fired rifle (Pneu Dart, Inc., Williamsport, PA). The remaining 35 adult radio-collared elk cows were untreated.

Following immunization, all collared animals were located twice monthly and observed at distances of 15 to 400 yards with binoculars and a sighting scope. Fecal samples were collected on all radio-collared females and on uncollared females for ovarian steroid hormone measurements. Details of the methods involved in the sample collection and laboratory analyses of these samples have been published elsewhere (Stoops and others 1999). Briefly, when individually identified animals defecated, the location of the feces was noted and a range finder was used to determine the distance to the animal from the point of observation. One person on a team used a hand-held radio to direct another to collect fecal samples, using laboratory gloves and plastic zip top bags. In general, more than one fecal sample was spotted for a particular group of elk cows. Time and distance were recorded, and location maps were drawn for each sample in order to maximize the number of samples collected per group. Fecal samples were also collected from specifically identified uncollared elk cows that were distinguished from collared cows or spike bulls. At least 5.0-g of fecal matter was collected and placed in appropriately labeled plastic bags. Samples were frozen within three to six hours of collection without preservatives until laboratory analyses.

Written records were kept for each group of elk encountered while hiking or riding the elk range. These records consisted of the location of the sighting, the time of the sighting, the total number of animals, the number of spike bulls, sub-prime branched bulls, branched bulls, cows and calves and a listing of all sighted radio-collars in the group. Continued attention to a radio-collared cow from prime and/or sub-prime bull past the time of the rut was recorded, and the cow involved was identified. The collection of additional demographic data during the calving season included calf confirmations determined by visual observance of nursing. All moralities observed were flagged and their locations were recorded. Radio-collars and ear tags were retrieved, if applicable.

Laboratory Methods

Fecal samples were logged into laboratory records on a computerized database. The identification code of the female elk and the date and location of collection were put onto a spreadsheet; hormone concentrations and conversion factors were added after assaying. Samples were thawed, and five grams of fecal material were placed into individual glass scintillation vials. The uncapped vials were then put into a drying oven, where they remained for 72 hours until totally dry. Dried fecal material was chopped into small fragments and powder. A dry weight of .250 grams fecal material was placed in a 16-x 100-mm glass test tube with 30 parts of 40% MeOH 60% EIA wash solubilizing solution, bringing the total weight of the dry feces and the solubilizer to 7.75 grams. Tubes were capped and shaken for 48 hours at room temperature. Tubes were next placed in a refrigerated centrifuge and spun at 5,000 rpms for 20 minutes. The supernatant was decanted into 12x75mm plastic tubes, and diluted with distilled water to the appropriate concentrations for each assay. Specific details of validation and application of enzyme immunoassays to tule elk fecal samples have been

described elsewhere (Stoops and others 1999). Estrogen and progesterone fecal metabolite profiles were used to identify cyclicity, conception and pregnancy loss. They were also used to anticipate parturition in the study animals, as well as to make comparisons between treated and untreated elk cows.

Statistical Methods

Standard descriptive statistics were used to summarize results. F Tests were performed to test whether the treated, nonpregnant and the untreated, pregnant elk cows had the same or equal variances in hormone excretion over the months studied.

Results

Of the 29 elk cows treated with pZP prior to the rut in 1997, 22 had calves from the previous year's rut. This represents 79% fertility for the treated cows in 1996. There is no reason to assume that this percentage is atypical or that it skewed the contraception result obtained, since 24, or 71%, of the 34 untreated radio-collared elk cows calved in consecutive years. In fact, six, or 43%, of the 14 remaining originally radio-collared animals from 1995 had calves for at least three consecutive years. Furthermore, a total of 11 elk cows, or 31% of the total untreated radio-collared population (n = 35), had calves for four consecutive years.

After treatment in the summer of 1997, and after calving in the spring and early summer of 1998, 77% of the untreated radio-collared cows calved compared to 7% of the treated radio-collared cows. Stated in reverse, 93% of the treated cows were infertile, compared with 23% of the untreated cows. Untreated cows included one-year and two-year old cows, which do not characteristically have calves at Point Reyes.

Based on fecal steroid evaluations, tables 1 and 2 show the percentages of untreated and treated cows sampled each month that were cycling or pregnant from May 1997 through April 1998. Stoops and others (1999) reported that steroid hormone metabolite levels prior to December could not be used to distinguish between cycling and early pregnant elk cows. This observation, paired with the additional observation that progesterone metabolite hormone levels of >1.01 µg/gr dwf (dry weight feces) from the month of December onward were 100% effective in diagnosing pregnancy in untreated radio-collared tule elk cows, were used to designate cows as either cycling or pregnant in these tables. Both groups (treated and untreated) show a high percentage of either cycling or pregnant elk cows, with the lowest percentage occurring in December for both groups. It is likely that the progesterone metabolite values of >1.01 µg/gr dwf in untreated elk cows, however, reflect pregnancy, whereas elevated values in the treated cows reflect ongoing cyclicity.

The annual endocrine profiles of the ovarian fecal steroid metabolites are depicted in figures 1-2. Figure 1 illustrates differences in the annual mean, unaligned estrogen metabolite levels of pregnant, untreated elk cows and treated, nonpregnant cows. In the untreated cows, mean, unaligned estrogen metabolite levels increase from 68.73 ± 43.52 (SD) ng/gr dwf in July to 101.56 ± 49.03 (SD) ng/gr dwf in November. Estrogen levels drop to lowest levels, 38.81 ± 11.77 (SD) ng/gr dwf in January, before beginning their pre-parturient climb toward peak values, 353.94 ± 337.46 (SD) ng/gr dwf in April. The estrogen profile for nonpregnant, treated, and therefore presumably continuously cycling, radio-collared elk cows has a similar pattern, but lower overall absolute levels, with a November high of 88.39 ± 52.67 (SD) ng/gr dwf, a January low of 35.88 ± 16.92 (SD) and an April climb to only 138.06 ± 196.51 (SD) ng/gr dwf. Figure 2 depicts differences between in the two groups with respect to mean, unaligned progesterone metabolite levels. In the untreated cows, progesterone metabolite levels increase from 1.81 ± 0.73 (SD) µg/gr dwf in July to 3.48 ± 2.15 (SD) µg/gr dwf in November. Progesterone metabolite levels then began their pre-parturient climb toward peak values, 4.89 ± 2.06 (SD) µg/gr dwf in May, falling only slightly in April to

Table 1—Estimated percentages of untreated radio-collared adult tule elk cows[a] cycling or pregnant and average ovarian fecal steroid hormone metabolite levels.

Month	N	%	Monthly average fecal estrogen metabolite levels, unaligned ng/gr. dwf[b] (±SD)	Monthly average progesterone metabolite levels, unaligned µg/gr. dwf (±SD)
May 1997	10	90.00	67.19 ± 22.54	1.45 ± 0.28
June 1997	15	100.00	48.71 ± 27.37	2.22 ± 0.54
July 1997	32	97.73	67.68 ± 48.28	1.99 ± 0.33
August 1997	18	67.00	92.98 ± 29.43	2.55 ± 0.96
September 1997	70	78.70	96.79 ± 33.78	2.71 ± 1.31
October 1997	120	83.85	73.34 ± 42.59	2.23 ± 0.80
November 1997	76	81.46	101.93 ± 45.54	2.64 ± 1.69
December 1997	64	54.68	82.17 ± 41.25	2.16 ± 1.48
January 1998	59	61.02	57.41 ± 21.15	2.88 ± 1.66
February 1998	44	84.60	80.38 ± 20.89	3.21 ± 1.73
March 1998	100	78.28	124.34 ± 95.77	3.95 ± 2.24
April 1998	45	82.22	267.49 ± 421.25	3.90 ± 2.51

[a]n = 95 (estimated effective breeding population of elk cows = 125 (Howell, pers. comm), minus the treated radio-collared group of 30 cows).
[b]dwf = dry weight feces.

Table 2—Estimated percentages of treated radio-collared adult tule elk cows[a] cycling or pregnant and average ovarian fecal steroid hormone metabolite levels.

Month	N	%	Monthly average fecal estrogen metabolite levels, unaligned ng/gr. dwf[b] (±SD)	Monthly average progesterone metabolite levels, unaligned µg/gr. dwf (±SD)
May 1997				
June 1997				
July 1997				
August 1997	29	79.31	49.30 ± 21.92	1.80 ± 0.82
September 1997	24	45.83	76.65 ± 21.67	2.47 ± 0.90
October 1997	28	81.25	73.59 ± 25.62	2.17 ± 1.04
November 1997	20	65.27	97.21 ± 58.50	2.64 ± 1.82
December 1997	21	35.10	96.98 ± 37.57	2.83 ± 2.69
January 1998	18	74.28	36.59 ± 18.02	2.64 ± 1.82
February 1998	12	66.67	80.93 ± 40.32	4.13 ± 1.71
March 1998	15	81.25	70.77 ± 15.43	2.94 ± 1.33
April 1998	28	71.30	237.00 ± 195.75	3.13 ± 1.90

[a]n = 28 (from an "n" of 30, excluding one cow that was not treated and one cow that was pregnant at the time of treatment and including two cows that conceived after treatment).
[b]dwf = dry weight feces.

4.20 ± 2.26 (SD) µg/gr dwf. The profile for nonpregnant, treated, radio-collared elk cows had a different pattern and different lower overall absolute levels, with a November high of 1.85 ± 1.92 (SD) ng/gr dwf, a February peak of 3.01 ± 2.23 (SD) and a March-April fall to 1.48 ± 3.89 (SD) µg/gr dwf and 1.71 ± 4.15 (SD) µg/gr dwf, respectively.

F Tests for comparison of hormone metabolites in treated, nonpregnant elk cows (n = 26) to those in untreated, pregnant elk cows (n = 27) over the period studied indicated a statistically significant difference between the two groups with respect to estrogen metabolite excretion over the year ($p > 0.00$), but none for progesterone metabolite excretion ($p > 0.07$).

Discussion

One of the consequences of the "Greening of America" and increased urbanization is an overabundance of certain wildlife populations such as deer, elk, mountain goats, skunks, and raccoons. The management of these wildlife populations is a major problem facing wildlife professionals that will not

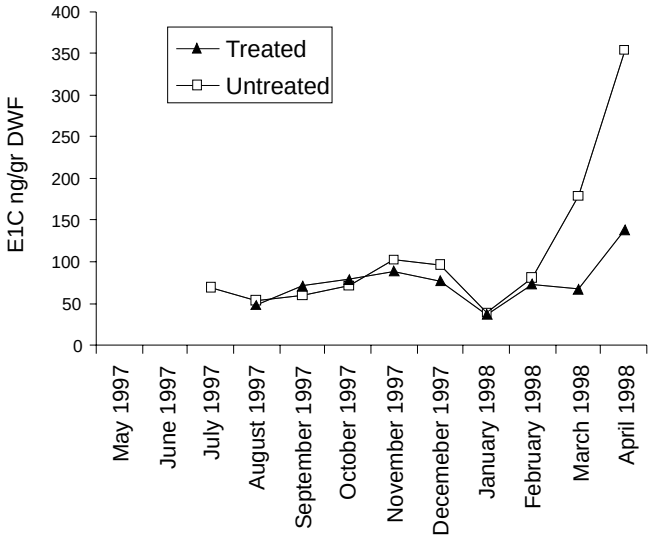

Figure 1—The annual endocrine profiles of annual mean, unaligned estrogen metabolites levels of pregnant, untreated elk cows and treated, nonpregnant cows. F Tests for comparison of fecal estrogen in treated, non-pregnant cows (n = 26) to those in untreated, pregnant cows (n = 27) over the period studied indicated a statistically significant difference between the two groups with respect to estrogen metabolite excretion over the year ($p > 0.001$).

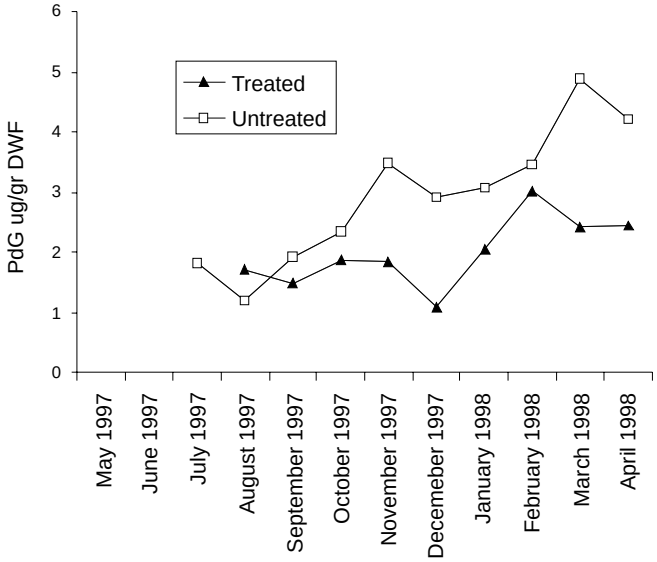

Figure 2—The annual endocrine profiles of annual mean, unaligned progesterone metabolites levels of pregnant, untreated elk cows and treated, nonpregnant cows. F Tests for comparison of fecal estrogen in treated, nonpregnant cows (n = 26) to those in untreated, pregnant cows (n= 27) over the period studied indicated no statistically significant difference between the two groups with respect to estrogen metabolite excretion over the year ($p > 0.07$).

be resolved easily. The dimensionality of the problem is complex, but not in terms of the biology or ecology of species involved; rather, the complexity stems from social, political, legal and economic concerns. For example, in the case of overly abundant white-tailed and mule deer, described by Conover (1997), these animals cause an estimated annual loss of two billion dollars (in car, crop, timber and household damage), but they have a recreational value of more than 12 billion dollars after subtracting losses. In addition, the presence of these deer in urbanized open spaces provide intangible but publicly recognized values, such as a general sense of well being and aesthetic pleasure, as well as ecological or biologic values like deer-induced alternate stable habitats (Conover 1997). Local experiences with the management of deer overabundance throughout the eastern United States suggest that solutions to urban wildlife overpopulation will require the mutual understanding and agreement of both the public and agencies involved on management goals and values to be preserved wherever intervention is needed.

While contraception cannot reverse population growth rates, it can slow them. Several credible programs have been initiated to develop artificial methods for population control, and some of these methods, such as immunocontraception, have been shown to be apparently safe and effective (Kirkpatrick 1990, 1991, 1994, 1995; Kirkpatrick and others 1995a, 1995b, 1997; Plotka and Seal 1989; Turner and others 1992, 1996; Warren and others 1992). The pZP (porcine zona pellucida) vaccine has been shown to be an effective immuno-contraceptive in Roosevelt elk and Rocky Mountain elk (Kirkpatrick and others 1996; Garrot and others 1998), but had not been used in tule elk prior to the use reported here. Using contraception to slow growth rates allows additional time for the further development of publicly acceptable management options that can reverse the growth rates, such as immuno-sterilization.

The results presented here on the California tule elk confirm that pZP vaccination is an effective contraception method for elk cows. Two of the treated cows were either pregnant before titers were high enough to prevent conception or became pregnant after treatment. These two cows received their initial immunization in early August and their boosters in the second week of September 1997. They both had live calves in late June and early July 1998, suggesting conception dates in early to mid-October. It is possible that a month—between the time of the second immunization and the approximate time of conception—was not long enough for the cows to mount an antibody response sufficient to prevent conception. Another alternative is that the amount of immunogen presumed to be delivered by remote darting was not delivered, and the dosage was, therefore, suboptimal. Nonetheless, pZP reduced the rate of calving in the treated group to >70% of that of the untreated group. In addition, according to J. A. Howell (1998), the rate of population increase in the Tomales Point elk herd in 1996-97 was approximately 32%. His population count in 1997-98 was 470 animals, an estimated rate of population increase of *ca*. 26% for that year. This is not a statistically significant reduction in the rate of increase, but it does coincide with the number of animals treated, suggesting that increasing the number of contracepted elk cows will continue slow reproduction and reduce this rate.

At the start of the rut in 1999, only 15% of the 13 initially treated elk cows from 1997 not given booster shots by dart gun in the summer of 1998 had calved by the summer of 1999 (2 out of 13 cows). This suggests the possibility that for perhaps as many as 85% of elk cows, annual booster shots may not be required. Additional booster shots may only be required every second or even every third year to maintain contraception. Furthermore, work in progress suggests that when pZP is presented to the elk cow immune system, depending on the formulation of the presentation, cows may be contracepted or sterilized with an initial immunization. These findings have useful implications for management. Single shot formulations and decreased immunization frequency will reduce the cost involved in contraception programs using pZP. Having a sterilization option provides an acceptable means of animal removal and of slowing the rate of increase while keeping resources occupied rather than freeing them for another animals' reproductive gain.

As stated earlier, these tools are especially valuable to private and public parks and recreation areas where traditional management tools can not be employed and where management's wildlife ethic is constrained by public opinion. The use of immuno-contraception with population monitoring of ovarian hormones to estimate fecundity in a given habitat, provides a lead-time to implement options for the next breeding season: maximal yield for a given population is predictable before calving takes place on the basis of fecundity estimates. The option presented here, fecal hormone monitoring and pZP immuno-contraception, together with work in progress on single-shot formulations of pZP contraceptive and sterilant, furnishes management with a few publicly acceptable tools to assist in animal population regulation required by increasingly common conditions of urbanization.

Acknowledgments

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References

Bartolome, J. W. 1993. Range analysis of the Tomales Point tule elk range: final report on award # 1443-px8530-93-206, on file at PORE. 14 p.

Boyce, M. S. 1998. Ecological-process management and ungulates: Yellowstone's conservation paradigm. Wildlife Society Bulletin. 26(3):391-398.

Carey, James R. 1993. Applied Demography for Biologists. New York, NY: Oxford University Press. 206 p.

Conover, M.R. 1997. Monetary and intangible valuation of deer in the United States. Wildlife Society Bulletin. 25(2):298-305.

Fayrer-Hoskens, R. A.; Bertschinger, H.; Turner, J. W. Jr.; Liu, I. K. M.; and J. F. Kirkpatrick. 1997.The management of African elephant populations by means of immunocontraception. Wildlife Society Bulletin. 25:18-21.

Garrott, R. A.; Crook, J. G.; Bernoco, M. M.; Kirkpatrick, J. F.; Cadwell, L. L.; Cherry, S.; and B. Tiller. 1998. Antibody response of elk immunized with porcine zona pellucida. Journal of Wildlife Diseases. 34(3):539-546.

Gogan, P. J. P. 1986. Ecology of the tule elk range, Point Reyes National Seashore. Ph.D. Dissertation. University of California, Berkeley. 441 p.

Hadidian, J. Science and the management of the white-tailed deer in the U.S. national parks. Pages 77-85 *in* W. E. Brown and S. D. Veirs, Jr., editors. Proceedings of the Seventh Conference on Research and Resource Management in Parks and on Public Lands: Partners in Stewardship; 1993; George Wright Society, Hancock, Michigan.

Howell, Judd A. 1998. Proposal on file at USGS, Biological Resources Division, Western Ecological Research Center, Golden Gate Field Station, Fort Cronkhite, Bldg.1063, Sausalito, CA, 94965.

Kirkpatrick, J. F.; Liu, I. K. M.; and J. W. Turner, Jr. 1990. Remotely-delivered immunocontraception in feral horses. Wildlife Society Bulletin. 18:326-330.

Kirkpatrick, J. F.; Liu, I. K. M.; Bernoco, M. M.; and J.W. Turner, Jr. 1991. Antigen recognition in mares previous-ly immunized with porcine zona pellucida. Journal of Reproductive Fertility. (Suppl.44): 321-325.

Kirkpatrick, J. F. 1995. Management of Wild Horses by Fertility Control: The Assateague

Experience. National Park Service Scientific Monograph, National Park Service, Denver, CO. 60 p.

Kirkpatrick, J. F.; Zimmermann, W.; Kolter, L.; Liu, I. K. M.; and J. W. Turner, Jr. 1995a. Immunocontraception of captive exotic species. I. Przewalski's horse (*Equus przewalski*) and the banteng (*Bos javanicus*). Zoo Biology. 14:403-416.

Kirkpatrick, J. F.; Naugle, R.; Liu, I. K. M.; Bernoco, M. M.; and J. W. Turner, Jr. 1995b. Effects of seven consecutive years of porcine zona pellucida contraception of ovarian function in feral mares. Biology of Reproduction. Monograph Series 1: Equine Reproduction VI: 411-418.

Kirkpatrick, J. F.; Calle, P. P.; Kalk, P.; Liu, I. K. M.; and J. W. Turner, Jr. 1996a. Immunocontraception of captive exotic species. II. Formosan sika deer (*Cervus nippon tiaouanus*), axis deer (*Cervus axis*), Himalayan tahr (*Hermitragus jemlahicus*), Roosevelt elk (*Cervus elaphus roosevelti*), muntjac deer (*Muntiacus reevesi*), and sambar deer (*Cervus unicolor*). Journal of Zoo and Wildlife Medicine. 27:482-495.

Kirkpatrick, J. F.; Gudermuth, D. F.; Mc Carthy, J. C.; Shideler, S. E.; and B. L. Lasley. 1996b. An assessment of the reproductive biology of the Yellowstone bison (*Bison bison*) subpopulations using non-capture methods. Canadian Journal of Zoology. 74:8-14.

Kirkpatrick, J. F.; Turner, J. W., Jr.; Liu, I. K. M.; Fayrer-Hoskin, R. A.; and A. T. Rutberg. 1997. Case studies in wildlife immunocontraception: wild and feral equids and white-tailed deer. Reproduction, Fertility, and Development. 9:105-110.

Mc Collough, D. R. 1969. The tule elk: its history, behavior, and ecology. University of California Publications in Zoology, Volume 88. University of California Press. 209 p.

Mc Collough, D. R.; Garrot, R .A.; Kirkpatrick, J. F.; Plotka, E. D.; Ralls, K. D.; and E. T. Thorne. 1993. Report of the Scientific Advisory Panel on Control of Tule Elk on Point Reyes National Seashore, USDI National Park Service, Point Reyes National Seashore. 42 p.

Plotka, E. D. and U. S. Seal. 1989. Fertility control in female white-tailed deer. Journal of Wildlife Diseases. 25:643-646.

Point Reyes National Seashore. 1998. Tule Elk Management Plan and Environmental Assessment. 94 p.

Stearns, Stephen C. 1993. The Evolution of Life Histories. New York, NY: Oxford University Press. 249 p.

Stoops, M. A.; Anderson, G.B.; Lasley, B. L.; and S. E. Shideler. 1999. Use of fecal steroid metabolites to estimate the pregnancy rate of a free-ranging herd of tule elk. Journal of Wildlife Management. 63(2):561-569.

Supernaugh, W. R. 1993. Wildlife issues in historical parks: management's perspective on white-tailed deer. Pages 96-98 *in* W. E. Brown and S. D. Veirs, Jr., editors. Proceedings of the Seventh Conference on Research and Resource Management in Parks and on Public Lands: Partners in Stewardship; 1993; George Wright Society, Hancock, Michigan.

Turner, J. W. Jr.; Liu, I. K. M.; and J. F. Kirkpatrick. 1992. Remotely delivered immunocontraception in captive white-tailed deer. Journal of Wildlife Management. 56:154-157.

Turner, J. W., Jr.; Liu, I. K. M.; and J. F. Kirkpatrick. 1996. Remotely delivered immunocontraception in free-roaming feral burros. Journal of Reproductive Fertility. 107:31-35.

Tzilkowski, W. M.; Fairweather, S. E.; Storm, G. L.; and T. W. Bowersox. 1993. Forest regeneration and white-tailed deer at Gettysburg National Military Park. Pages 86-95 *in* W. E. Brown and S. D. Veirs, Jr., editors. Proceedings of the Seventh Conference on Research and Resource Management in Parks and on Public Lands: Partners in Stewardship; 1993; George Wright Society, Hancock, Michigan.

Warren, R. J.; Fayrer-Hoskin, R. A.; Garrot, R. A.; Jessup, D. A.; and J. F. Kirkpatrick. 1992. The applicability of contraceptives in the elimination or control of exotic mountain goats from Olympic National Park. Scientific Panel Review for the National Park Service. 35 p.

Dynamics of Chinook Salmon Populations Within Idaho's Frank Church Wilderness: Implications for Persistence

Russell F. Thurow

Abstract—Research was begun in 1995 to describe factors influencing the spatial dynamics and persistence of federally listed chinook salmon within the Frank Church River of No Return Wilderness. Results addressed two objectives: 1) description of chinook salmon redd distributions, and 2) comparison of index and total redd counts. Annual redd counts ranged from 20 to 661, and 99% of redds were constructed in tributaries. Redds were observed at elevations between 1,140 and 2,070 m, with a majority (56%) >1,900 m. The distribution of redds deviated from a random pattern and fluctuated with adult salmon numbers. At lower adult escapements, redds were clustered in specific areas of a few watersheds. At higher escapements, fish constructed additional redds near previous clusters and also outside of clusters and in watersheds that were previously not utilized. Index area counts averaged 63% of total counts.

The Columbia and Snake River basins historically supported large runs of chinook salmon (*Oncorhynchus tshawytscha*). Estimates of annual chinook salmon returns to the Columbia River prior to 1850 ranged to 6.4 million fish (Northwest Power Planning Council 1986). Despite several decades of habitat alteration and commercial harvest by the late 1880s, an estimated 1.5 million chinook salmon returned annually to the Snake River in that decade (Bevan and others 1994). Many native Americans depended on salmon as a subsistence and ceremonial resource (Northwest Power Planning Council 1986). Since European settlement, salmon and other anadromous species have continued to influence social and economic systems (Thurow and others 2000).

Today, chinook salmon and other anadromous fishes native to the Snake River are imperiled. All Snake River anadromous salmonids, including stream-type (spring and summer), and ocean-type (fall) chinook salmon, steelhead (*O. mykiss*), and sockeye salmon (*O. nerka*), are listed as threatened or endangered under the Endangered Species Act of 1973 (ESA). Coho salmon (*O. kisutch*) have been extirpated from the Snake River (Lee and others 1997). Pacific lamprey (*Lampetra tridentata*) have declined dramatically. Harrison (1995) reported that in the 1960s nearly 50,000 lamprey were counted at Ice Harbor Dam; less than 400 were counted in 1994.

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Since European settlement of the Snake and Columbia river basins, a plethora of factors have contributed to declines in the distribution and abundance of chinook salmon. These include blocked access to historical habitat, passage mortality at dams and obstructions, freshwater and estuaries habitat degradation, overharvest, and interactions with hatchery-reared and nonnative fishes. Thurow and others (2000) reported that stream-type chinook salmon have been extirpated from more than 70% of their potential historical range, and strong populations remain in 1.2% of the current range in portions of the Columbia River and Klamath River basins east of the Cascade Crest. An estimated 12,452 km of potential historical habitat have been blocked and are no longer accessible to anadromous fish in the Snake and Columbia river basins (Northwest Power Planning Council 1986). Nehlsen and others (1991) identified habitat loss or degradation as a major problem for 90% of the 195 at-risk salmon and steelhead stocks they identified.

Although a variety of factors over many decades have influenced declines in Snake River anadromous fish, construction and operation of mainstem dams is considered the proximate cause of recent declines (Columbia Basin Fish and Wildlife Authority 1990). Smolt-to-adult return rates declined from more than 4% in 1968 (Raymond 1979) to less than 0.5% in the 1990s (Marmorek and others 1998). As a result of low flows in the migration corridor in 1973 and 1977, 95% of migrating smolts never reaching the ocean (Raymond 1979). The influence of passage mortality was further illustrated by Huntington and others (1996) and Lee and others (1997), who reported that no healthy or strong populations of anadromous fish were found in the central Idaho wilderness, even though it contains some of the Pacific Northwest's highest quality spawning and rearing habitat.

In response to declining populations and ESA requirements, agencies have adopted policies that attempt to conserve and restore remaining chinook salmon populations. These have included measures to maintain genetic integrity of remaining wild stocks, reduce passage mortality by improving conditions in the migration corridor, reduce the effects of exotics, restrict sport and commercial harvest, and adopt measures to conserve or restore remaining critical habitat. The conventional approach to managing critical habitat focused on conserving or restoring the quality of remaining habitats–that is, conserving and restoring those habitats considered necessary for chinook salmon to complete their complex life cycle from an incubating egg to a mature fish depositing eggs in natal spawning areas.

While conservation of the quality of critical habitats is essential, there is growing concern that the size and spacing

of habitats also needs to be considered (Krohn 1992). Simberloff (1988) suggested that effective conservation may require maintaining or restoring a critical amount or mosaic of habitat, as well as habitat of certain quality. Recent papers support the hypothesis that conservation of declining salmonid stocks may require attention to spatial concepts (Frissell and others 1993; Rieman and McIntyre 1993). In an empirical study of larger scale processes, Rieman and McIntyre (1995) reported that habitat area influenced the distribution of disjunct populations of bull trout (*Salvelinus confluentus*) and suggested that larger-scale spatial processes may be important to salmonid persistence. The relevance of these concepts to declining populations of chinook salmon is unknown.

In 1995, scientists at the Rocky Mountain Research Station initiated research to describe factors influencing the spatial dynamics of declining populations of chinook salmon. The central hypothesis states that habitat area, habitat quality, or habitat context (location in relation to other populations) influences the occurrence of spawning chinook salmon. If the hypothesis is true, recolonization and persistence of chinook salmon populations may be strongly influenced by the spatial geometry of remaining habitats. The hypothesis is being tested by describing the distribution of chinook salmon redds and potential spawning areas in a large, relatively undisturbed wilderness basin. Although a suite of objectives are being addressed, this paper reports results addressing two objectives: 1) describe the temporal and spatial distribution of chinook salmon redds and 2) compare index and non-index area redd counts. This research represents the first comprehensive survey of redds in the study area and provides information on the temporal and spatial dynamics of chinook salmon in a large wilderness watershed. In addition to addressing larger scale spatial questions about persistence, this research provides an estimate of the total number of redds constructed in the study area, enabling managers to estimate total adult escapement.

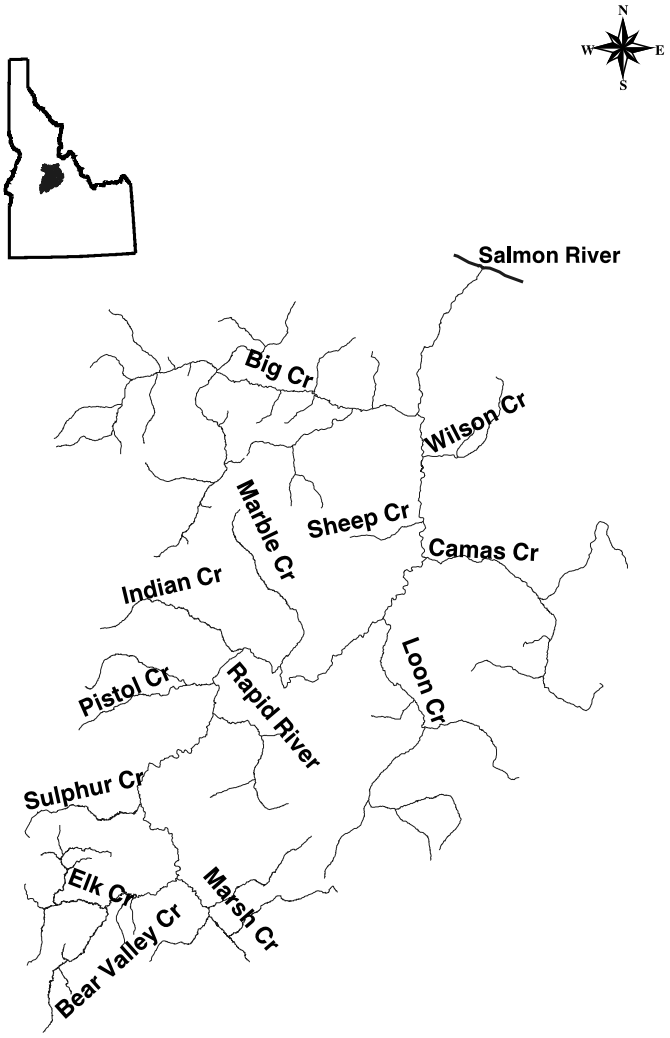

Figure 1—Potential chinook salmon spawning tributaries in the Middle Fork Salmon River drainage, Idaho.

Study Area

The Middle Fork Salmon River (MFSR), a National Wild and Scenic River, drains about 7,330 km^2 of a remote area of central Idaho. For most of its length, the river flows through the Frank Church River of No Return Wilderness (FC-RONRW). The MFSR drainage provides critical habitat for six ESA listed species: bald eagle (*Haliaeetus leucocephalus*), peregrine falcon (*Falco peregrines*), grey wolf (*Canis lupus*), chinook salmon, steelhead, and bull trout. From its origin at the confluence of Bear Valley and Marsh Creeks, the MFSR flows north-northwest for 171 km through the Salmon River mountains and joins the Salmon River 92 km downstream from Salmon, Idaho (fig. 1). Twelve major streams and hundreds of smaller ones are tributary to the river. Human access in the lower 156 km of the main river and most tributaries is limited to a few airstrips, float craft, or by trail. From 1930-1980, a majority of the region was managed in "Primitive Area" status (US Forest Service 1998). In 1980, the Central Idaho Wilderness Act established the 906,136 hectare wilderness that remains the largest contiguous wilderness in the lower 48 states and the largest in the National Forest system. The Gospel Hump and Selway-Bitterroot wilderness area border the FC-RONRW and together comprise nearly 1.6 million hectares (US Forest Service 1998). In 1984, the current name was adopted in honor of the late Senator Frank Church's efforts to secure wilderness designation.

Elevations range from >3,150 m in adjacent mountains to 1,550 m at the rivers' confluence. The topography has high relief. The geology of the area is highly variable and dominated by Challis Volcanics (Eocene age) and intrusions of the Casto Pluton phase (Tertiary age) of the Idaho Batholith (Minshall and others 1981). The climate is semiarid, with most precipitation falling as snow. Climate varies markedly with elevation; precipitation ranges from 38-50 cm in lower valleys to 76-100 cm at higher elevations (Minshall and others 1981). Maximum daily air temperatures range from -30 to >33 °C. Vegetation also varies by elevation, with sagebrush (*Artemsia* sp), grasses and shrubs common in lower elevations and on south-facing slopes. Various conifers including ponderosa pine (*Pinus ponderosa*), Douglas fir

(*Pseudotsuga menziesii*), subalpine fir (*Abies lasiocarpa*) and whitebark pine (*Pinus albicaulis*) populate higher elevations. Riparian vegetation includes alder (*Alnus* sp), aspen (*Populus tremuloides*), water birch (*Betula occidentalis*), cottonwood (*Populus balsam fera*) and willow (*Salix* sp) (Minshall and others 1981).

Native Americans inhabited the area and utilized its salmon resources for at least 10,000 years (Knudson and others 1982). Euroamericans first described the drainage in 1824, when Alexander Ross traveled along Marsh Creek. The MFSR was a major production area for chinook salmon in the Columbia River Basin. Chapman (1940) reported that "the Middle Fork of the Salmon possesses immense spawning areas for spring chinook which to my knowledge are not surpassed or even reached in quantity or quality any place else in the Columbia River drainage."

The drainage supports 15 native fishes including seven salmonid taxa: bull trout, westslope cutthroat trout (*Oncorhynchus clarki lewisi*), redband trout (*O. mykiss* ssp.), mountain whitefish (*Prosopium williamsoni*), steelhead and spring and summer chinook salmon forms (Thurow 1985). Columbia River basin chinook salmon have traditionally been described as spring, summer and fall races—separated primarily by their time of passage over Bonneville Dam (Matthews and Waples 1991). Spring chinook salmon cross Bonneville Dam from March to May, summers from June to July, and falls from August to September (Burner 1951). Healey (1991) categorized juvenile chinook salmon that migrate seaward after one or more years as stream-type and those that migrate as subyearlings as ocean-type. I adopted these definitions to characterize chinook salmon stocks in the study area. Within the MFSR, stream-type chinook salmon include spring- and summer-run fish (Fulton 1968; Gebhards 1959; Idaho Department of Fish and Game 1992; Parkhurst 1950).

Importance of the Wilderness Study Area

The wilderness study area was selected for four reasons. First, remaining chinook salmon stocks are wild and indigenous, unaltered by hatchery supplementation. Consequently, the ability of the salmon population to respond to the quality and quantity of the available habitat has not been altered. Hatchery programs could confound a spatial analysis by influencing population levels in two ways: 1) hatchery supplementation may erode genetic diversity and alter coadapted gene complexes characteristic of locally adapted stocks (Reisenbichler 1997; Waples and Do 1994), resulting in a loss of both fitness (such as growth, survival, and reproduction) and genetic variability important to long-term stability and adaptation in varying environments, 2) in degraded habitats, hatchery programs that rely on smolts could inflate the salmon population that would be present if recruitment were supported solely by the amount and quality of freshwater habitat. Wild, indigenous, stream-type chinook salmon populations like those in the MFSR are rare; Thurow and others (2000) reported their presence in 4% of the potential historical range and 15% of the current range in the Columbia River basin and portions of the Klamath River basin.

Second, most of the MFSR drainage has been relatively undisturbed by anthropogenic influences, so habitat quality has not been substantially altered. Although a majority of the MFSR drainage and its aquatic habitat is in a relatively pristine state, past anthropogenic activity has degraded habitat in some areas. Livestock grazing has degraded riparian and in-stream habitat in reaches of the Bear Valley, Camas and Marsh Creek drainages, and historical mining activities altered habitat in the reaches of the Bear Valley, Camas, Loon and Marble Creek drainages. Because past perturbations have largely been eliminated since wilderness designation, and with the additional land-use constraints since ESA listing of stocks, much of the degraded habitat is recovering. Numerous studies describe the negative effects of land-use activities on freshwater habitat conditions and link habitat conditions to survival and productivity of anadromous fish (Meehan 1991; Murphy 1995; National Research Council 1986). Widespread degradation of habitat would be expected to confound a spatial analysis of freshwater habitat by influencing fish distribution and abundance.

Third, few introduced species are present within the range of chinook salmon in the MFSR. Only brook trout (*Salvelinus fontinalis*) have been observed within known chinook salmon spawning and rearing areas (Thurow 1985). Introduction of other nonnative salmonids, including forms of rainbow trout and cutthroat trout, golden trout (*O. aguabonita*), and arctic grayling (*Thymallis arcticus*), have been confined to formerly fishless high-elevation lakes. Predation, competition and genetic introgression from nonnative species can influence the status of salmon populations (Thurow and others 2000). In degraded habitats, introduced species may pose an even larger risk to native species (Hobbs and Huenneke 1992).

Fourth, the large area provides an opportunity for a large sample size. About 650 km of tributaries and 170 km of the mainstem are accessible to chinook salmon (Mallet 1974; Thurow 1985). This increases the likelihood of a sample size large enough to complete a robust spatial analysis.

Methods

The importance of spatial concepts to persistence of chinook salmon was initially tested by describing the distribution of chinook salmon redds within the Middle Fork Salmon River drainage. First, I selected areas with the potential to support spawning fish. Second, areas were annually surveyed to count chinook salmon redds. A global positioning system (GPS), was used to spatially locate salmon redds which were mapped using a geographic information system (GIS). Redd elevations and the linear distance of redd distribution along streams were calculated and compared among years with different spawning escapements. Finally, I annually compared redd counts in index areas with total counts.

Selection of Study Streams

Chinook salmon require access to and specific microhabitat conditions in spawning locations. Consequently, not all areas of the MFSR have the potential to support redds. I selected potential study streams by reviewing past redd surveys, reviewing anecdotal accounts of redds and

spawners, contacting biologists familiar with the drainage and reviewing records of juvenile chinook salmon occurrence. Existing information suggests that a total of 12 tributaries and about 145 km (headwaters to Big Creek) of the mainstem MFSR have the potential to support spawning populations of chinook salmon. Chinook salmon redds were counted in the MFSR beginning in 1947, and counts have been consistently completed in six MFSR tributaries since 1957 (Hassemer 1993). Redd counts in 1953 documented chinook salmon spawning in the mainstem MFSR and the Bear Valley, Big, Camas, Indian, Loon, Marble, Marsh, Rapid River and Sulphur Creek drainages (Hauck 1954). Gebhards (1959) reviewed historical information and also reported chinook salmon spawning in the Pistol and Wilson Creek drainages. Juvenile chinook salmon and suitable chinook salmon spawning habitats were observed by Thurow (1985) in 10 of the 11 streams listed above. Despite no record of chinook salmon spawning, I included Sheep Creek as a potential spawning stream because it is accessible and supports suitable spawning habitat. These 12 tributaries and the mainstem MFSR total more than 800 km of accessible habitat. The remaining tributaries to the MFSR were judged to be too steep or too small to support spawning chinook salmon (Gebhards 1959; Ball 1995).

Redd Counts

From 1995-1998, annual redd counts were completed in each of the 12 streams and in the reaches of the mainstem MFSR described above. I flew all of the accessible stream reaches in the survey area and observed redds from a low-flying helicopter. All flights were conducted after chinook salmon had completed spawning and while redds were still visible. Based on IDFG index area surveys (Hassemer 1993), interviews with biologists who survey MFSR index areas, and my own observations, chinook salmon typically complete spawning by September 8. All redd count flights were completed from September 8-14 1995-1998. We completed surveys between 0900 and 1800 hours to increase the likelihood of direct overhead sunlight. Flights required about 40 hours of aerial census time per year.

During counts, the pilot maintained the slowest airspeed possible and hovered the helicopter (a turbo Hiller Saloy) at an altitude ranging from 15 to 50 m above the streambed, depending on the terrain and presence of trees and cliffs. As the primary observer, I wore polarized sunglasses and searched for the characteristics pit and tailspill morphology of chinook salmon redds (Burner 1951) in potential spawning areas.

Redd dimensions illustrate the area of disturbed gravel I was searching for: Burner (1951) reported an average area of 3.3 m^2 for 184 spring chinook salmon redds, and King and Thurow (1991) reported an average area of 4.7 m^2 for 30 summer chinook salmon redds. Redd dimensions tend to be proportional to the length of spawning fish (Burner 1951; Crisp and Carling 1989; Ottaway and others 1981) and MFSR chinook salmon are of similar size to those studied by King and Thurow (1991).

After observing a redd, I immediately recorded its position with a global positioning system (GPS) mounted in the ship. For ease of recording, I used a data dictionary and recorded redds as point features in a GPS file. One of the benefits of the helicopter was the ease with which it could be used to resurvey an area. For example, if I wanted a second look, the pilot hovered the craft and re-flew the area in question.

Some portions of the study area were not adequately surveyed from a helicopter. Narrow streams with a large amount of tree canopy and shading were particularly difficult. I recorded the areas where I was unable to complete aerial surveys. Crews returned to the areas where aerial counts were incomplete and completed ground-based redd surveys. During ground surveys, two observers wore polarized sunglasses, walked parallel on adjacent stream banks and recorded redd locations with a portable GPS unit. Both mainstem stream reaches and side channels were surveyed.

Comparison of Index and Total Counts

I compared annual redd counts in seven index areas with total counts in the drainage. Index area counts were completed in low-gradient reaches and completed during the "peak" spawning period, typically in August (Hassemer 1993). Total counts were derived by summing the results of the September aerial and ground-based surveys described above.

Results

Since 1995, annual redd counts have ranged from 20 to 661 (table 1). A total of 1,188 redds were observed from 1995 to 1998. Chinook salmon spawned in both mainstem reaches of the Middle Fork Salmon River and tributaries, with 98.9% of the redds observed in tributaries. With the exception of 1995, the Bear Valley and Marsh Creek drainages supported the largest number of redds, followed by varying numeric order in the Loon, Sulphur and Camas Creek drainages. I consider these minimum total counts because several areas were not completely counted in certain years. In 1995, intensive rainfall created turbid water conditions and prevented complete counts in the Camas and Loon Creek drainages and in the mainstem downstream from Loon Creek. In 1997, intensive rainfall created turbid water conditions and prevented complete counts in the mainstem downstream from Bernard Creek. In 1998, intensive rainfall created turbid water conditions and prevented complete counts in Loon Creek downstream from Cold Springs Creek and in the mainstem downstream from Loon Creek.

Redds were observed at elevations between 1,140 to 2,070 m (fig. 2). Most (56%) of the redds were observed in spawning areas above 1,900 m elevation in the Bear Valley and Marsh Creek drainages. The East Fork Mayfield Creek in the headwaters of the Loon Creek drainage also supported redds above 1,900 m. The Big, Camas, Loon and Sulphur Creek drainages supported redds in the 1,700-1,800 m range. The lowest elevation redds (<1,200 m) were consistently observed in lower reaches of the Big Creek drainage.

The distribution of redds deviated from a random pattern (figs. 3, 4, 5, and 6). Redd distribution also fluctuated with adult salmon numbers. At lower adult escapements, redds were clustered in specific areas of a few watersheds. At higher escapements, fish constructed additional redds near

Table 1—Chinook salmon redd counts in tributaries to and in the mainstem Middle Fork Salmon River, Idaho, 1995-1998.

Drainage	Stream	1995	1996	1997	1998	Totals
Bear Valley	Bear Valley	9	19	47	116	191
	Elk	0	17	106	112	235
Big	Big	9	8	44	38	99
	Monumental	0	0	8	18	26
Camas	Camas	0	5	26	65	96
Indian	Indian	1	0	5	4	10
Loon	Loon	0	5	51	71	127
Marble	Marble	0	1	21	13	35
Marsh	Marsh	0	8	41	61	110
	Beaver	0	1	8	32	41
	Capehorn	0	5	24	42	71
	Knapp	0	0	1	6	7
Pistol	Pistol	0	1	7	3	11
RR	RR	0	1	7	8	16
Sulphur	Sulphur	1	11	21	67	100
Mainstem MFSR	reaches	0	1	7	5	13
	Totals	20	83	424	661	1188

previous clusters and also outside of clusters and in watersheds that were previously not utilized.

Figure 7 and table 1 illustrate the change in the linear distribution of redds in some example drainages. Viewing mainstem Bear Valley Creek, for example, in 1995 nine redds were distributed along 14.8 km, compared with 19 redds along 24.8 km in 1996, 47 redds distributed along 40.7 km in 1997 and 116 redds distributed along 44.5 km in 1998.

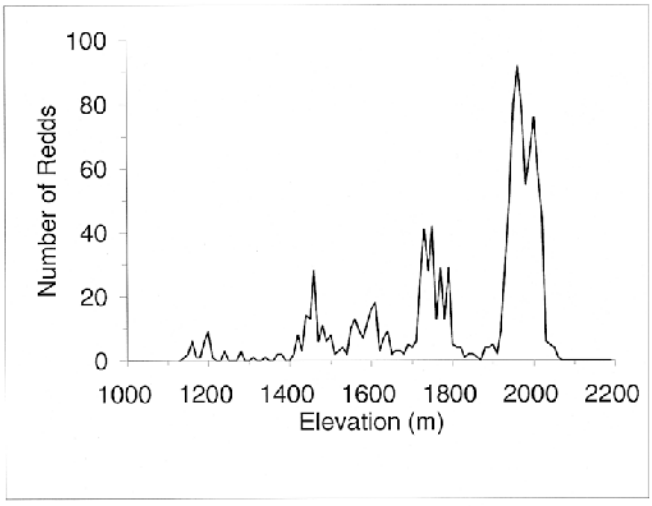

Figure 2—Elevation of 1,188 redds observed in the Middle Fork Salmon River, Idaho, 1995-1998.

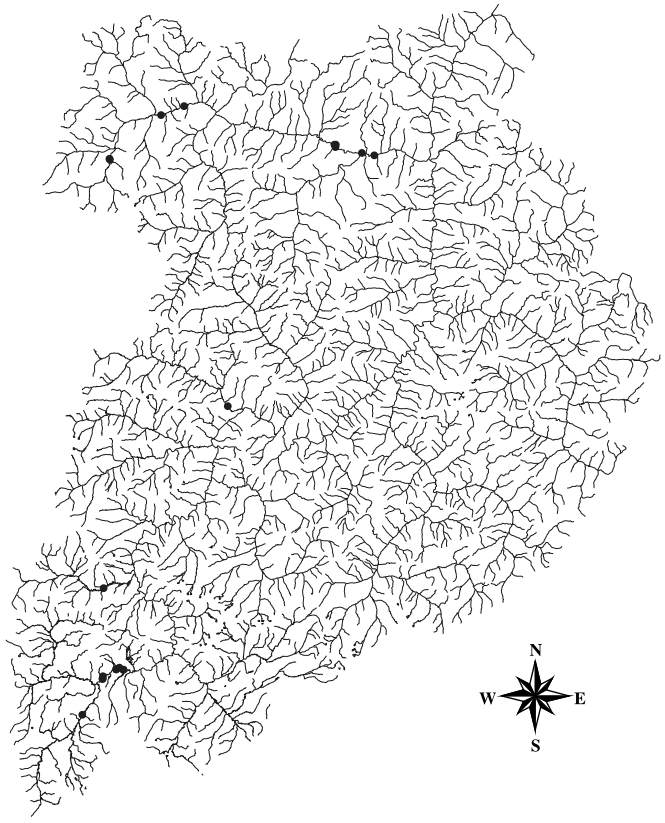

Figure 3—Distribution of chinook salmon redds in the Middle Fork Salmon River, Idaho, 1995.

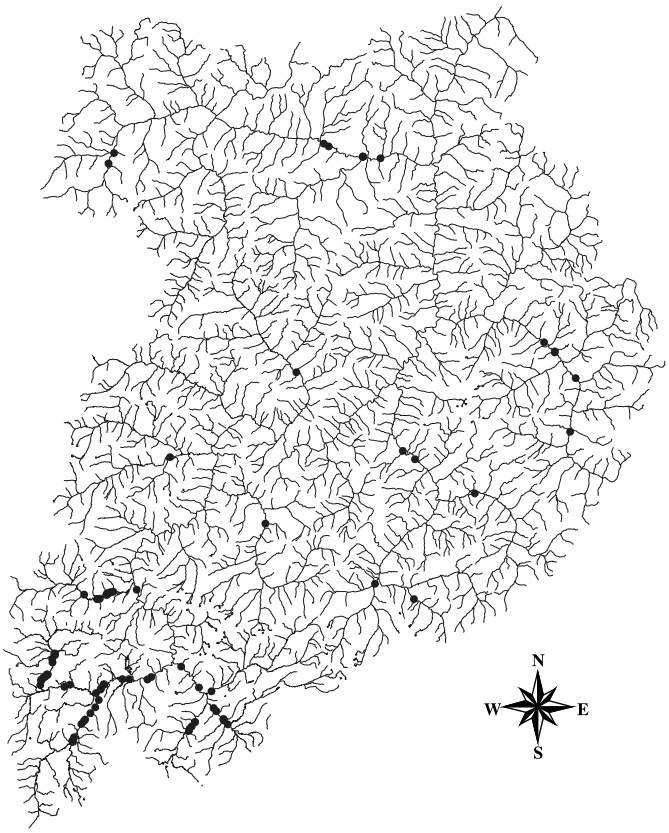

Figure 4—Distribution of chinook salmon redds in the Middle Fork Salmon River, Idaho, 1996.

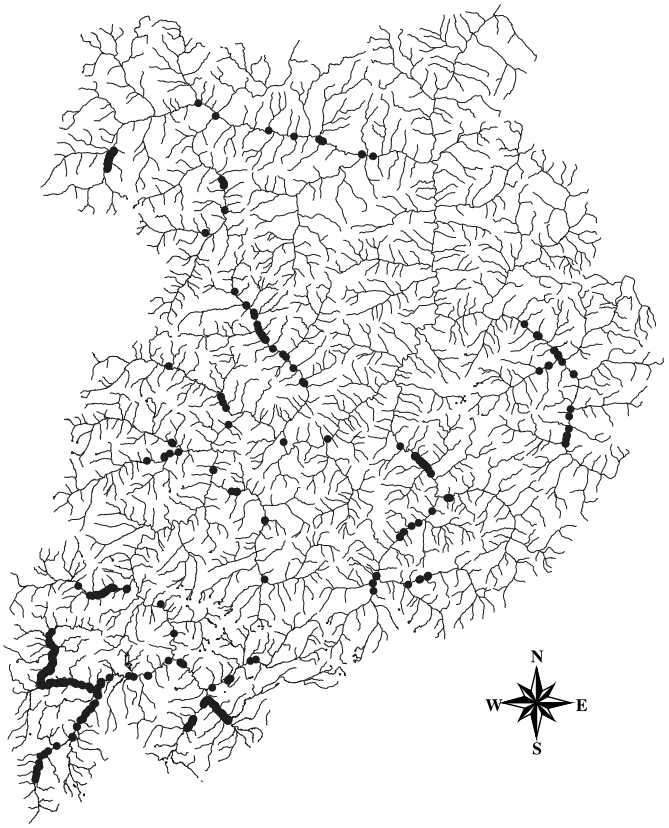

Figure 5—Distribution of chinook salmon redds in the Middle Fork Salmon River, Idaho, 1997.

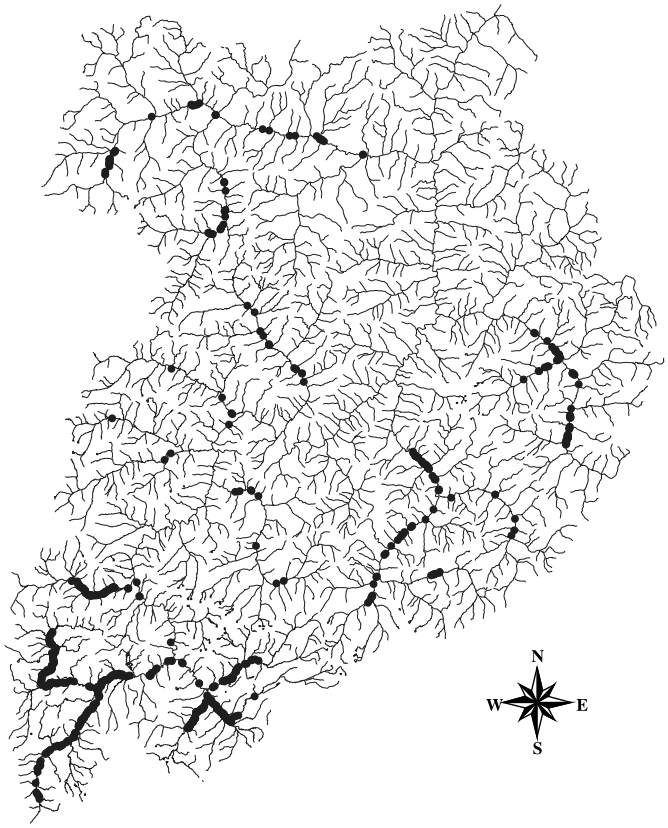

Figure 6—Distribution of chinook salmon redds in the Middle Fork Salmon River, Idaho, 1998.

I compared annual index area counts in seven streams with total annual redd counts. Index counts accounted for from 58% to 76% of the total redds counted within index areas (table 2). Index area counts averaged 63% of total counts in the entire study area (fig. 8).

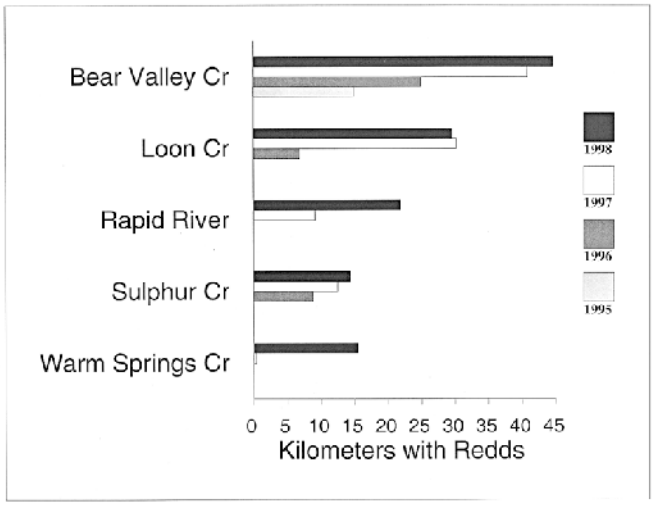

Figure 7—Kilometers of selected spawning tributaries supporting redds in the Middle Fork Salmon River, Idaho, 1995-1998.

Table 2—Chinook salmon redds counted in index and total surveys in tributaries to the Middle Fork Salmon River, Idaho, 1995-1998.

Drainage	Stream	Year surveyed	Number of redds observed	
			Index survey	Total survey
Bear Valley	Bear Valley Cr.	1995	9	9
		1996	15	19
		1997	38	47
		1998	102	116
	Elk Cr.	1995	0	0
		1996	17	17
		1997	86	106
		1998	105	112
Big	Big, Monumental creeks	1995	2	9
		1996	1	8
		1997	33	52
		1998	15	56
Camas	Camas, West Fk Camas creeks	1995	No count	No count
		1996	1	5
		1997	7	26
		1998	16	65
Loon	Loon, Warm Springs, Mayfield creeks	1995	No count	No count
		1996	1	5
		1997	22	51
		1998	42	71
Marsh	Marsh, Capehorn, Beaver, Knapp creeks	1995	0	0
		1996	10	14
		1997	62	74
		1998	88	141
Sulphur	Sulphur Cr.	1995	0	1
		1996	13	11
		1997	15	21
		1998	47	67

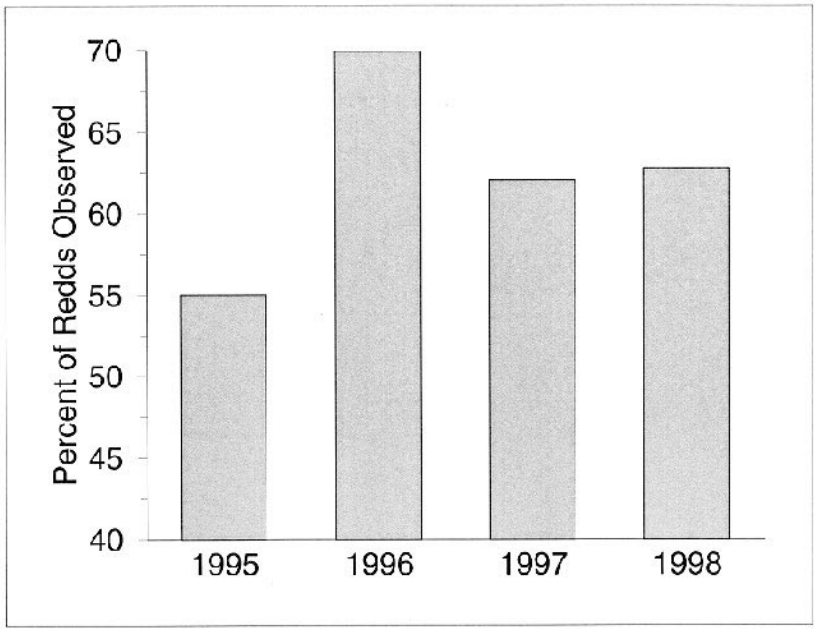

Figure 8—The percent of total chinook salmon redds in the Middle Fork Salmon River, Idaho, counted in index area surveys.

Conclusions

Redd counts from 1995-1998 suggest two main conclusions about the chinook salmon studied here. First, chinook salmon in the MFSR appear to retain a strong tendency to return to natal areas to spawn. Second, the distribution of redds outside of clusters and the change in linear distribution of redds in MFSR tributaries suggest that some chinook salmon may not return to natal areas but instead "stray" and spawn in non-natal habitats. Both features have important implications for the persistence of wild chinook salmon.

The clustering of redds in specific areas of the watersheds I studied supports the premise that most salmon retain high fidelity and "home" to natal areas. As Labelle (1992) observed, one of the distinguishing features of Pacific salmon is their ability to return to their natal streams to spawn and die. If redd clusters occur annually in the same areas, this would suggest that progeny from earlier spawning continue to return as adults and spawn in natal areas. The homing ability of chinook salmon was one of the premises for establishing "index" areas to monitor MFSR chinook salmon (Hassemer 1993). The ecological importance of this homing is partially linked to nutrient influx. As Larkin and Slaney (1997) observed, an adult salmon's body mass is almost entirely of marine origin. As a result, salmon secure the link between the marine and freshwater environment via the annual return of adults to natal areas, of which many, like the MFSR, are very oligotrophic. By returning to natal areas, adult salmon substantially contribute nutrients that may influence the growth and survival of juvenile salmon (Bilby and others 1996; Kline and others 1990), as well as contributing nutrients to terrestrial plants and animals.

Observations at higher escapements that more redds are distributed outside clusters and redds are distributed along longer distances in streams may indicate straying. Straying is the process by which new habitats are colonized (Labelle 1992) or the process by which populations that become extirpated may be refounded by adjacent populations (Hanski and Gilpin 1991). Although natural rates of straying have rarely been assessed, data suggest there is both a temporal and spatial pattern to straying. Straying appears to be related to proximity to the natal river (Labelle 1992; Quinn 1993), as well as the physical conditions in the watershed. Straying may also be related to demographic (older salmon stray more than younger salmon) (Quinn 1993) and density characteristics.

As noted in the introduction, the research results reported here begin to address two of several objectives of a larger research program. The 1995-1998 results can also be considered preliminary because of temporal variation. Returns of adult chinook salmon are influenced by a variety of factors, including migratory corridor (Raymond 1979) and ocean conditions (Lichatowich and Mobrand 1995). Therefore, adult escapements and corresponding redd counts will fluctuate annually. Because of this variation, it will be necessary to follow a minimum of one full generation of chinook salmon to adequately complete an analysis of spatial dynamics.. The age structure of spring and summer chinook salmon that spawn in the MFSR includes precocial males that mature after one or two years in freshwater, jacks that mature after two or three years in freshwater and 1 year in the ocean, and males and females that mature after two or three years in freshwater and two or three years in the ocean (Idaho Department of Fish and Game and others 1990). An occasional fish will spend four years in salt water. As a result of this variable age structure, the spawners in an individual year may range from one to seven years old. One generation would encompass seven years. Consequently, the data from 1995-1998 represent an initial step in addressing larger scale spatial questions about persistence.

As described above, the wilderness designation of the study area is critical to the completion of this research. Within the large FC-RONRW wilderness, the factors influencing the spatial dynamics of chinook salmon populations can be studied without the confounding effects of human activities. Further, designated wilderness and unroaded areas are important anchors for several native salmonids (Lee and others 1997) in addition to supporting some of the last remaining indigenous stocks of chinook salmon and steelhead (Thurow and others 2000). Although the declines in Snake River chinook salmon in recent years can be attributed primarily to mainstem dams, until passage problems are resolved, the resiliency and persistence of remaining chinook salmon populations will be largely dependent on the quality and diversity of remaining freshwater habitat (Lee and others 1997). The FC-RONRW will be key because it retains some of the highest quality salmon spawning and rearing habitat in the Columbia River Basin (Huntington and others 1996).

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References

Ball, K. 1995. Personal communication of information on chinook salmon redd locations. Idaho Department of Fish and Game. Salmon.

Bevan, D.; Harville, J.; Bergman, P. [and others]. 1994. Snake River salmon recovery team: Final recommendations to the National Marine Fisheries Service—summary. Portland, OR. 25 p. + Appendices.

Bilby, R. E.; Fransen, B. R., and Bisson, P. A. 1996. Incorporation of nitrogen and carbon from spawning coho salmon into the trophic system of small streams: evidence from stable isotopes. Canadian Journal of Fisheries and Aquatic Sciences. 53 (1): 164-173.

Burner, C. J. 1951. Characteristics of spawning nests of Columbia River salmon. U.S. Department of the Interior, Fish and Wildlife Service, Fishery Bulletin. 52: 97-110.

Columbia Basin Fish and Wildlife Authority. 1990. Integrated system plan for salmon and steelhead production in the Columbia Basin. Northwest Power Planning Council, 851 SW Sixth Avenue, Suite 1100, Portland, OR. 442p.

Chapman, W. M. 1940. Report of a field trip to the Snake River drainage in Idaho and Eastern Oregon, 1940. Washington Department of Fisheries. Olympia.

Crisp, D. T.; Carling, P. A. 1989. Observations on siting, dimensions, and structure of salmonid redds. Journal of Fish Biology 34: 119-134.

Frissell, C.A.; Liss, W.J.; Bales, D. 1993. An integrated, biophysical strategy for ecological restoration of large watersheds. In: Potts, D., ed. Proceedings of the symposium on changing roles in water resources management and policy. Herndon, VA: American Water Resources Association: 449-456.

Fulton, L.A. 1968. Spawning areas and abundance of chinook salmon, *Oncrhynchus tshawytscha,* in the Columbia River Basin—Past and present. U. S. Department of the Interior, Fish and Wildlife Service Special Scientific Report. Fisheries 571.

Gebhards, S. V. 1959. Columbia River Fisheries Development Program. Salmon River Planning Report. Boise, ID: Idaho Department of Fish and Game.

Hanski, I.; Gilpin, M. 1991. Metapopulation dynamics: brief history and conceptual domain. Biological Journal of the Linnean Society. 42: 3-16.

Harrison, J. 1995. The forgotten fish. Northwest energy news. 14(3): [pages]. Portland, OR: Northwest Power Planning Council.

Hassemer, P. F. 1993. Salmon spawning ground surveys, 1989-1992. Project F-73-R-15. Idaho Department of Fish and Game. Boise.

Hauck, F. R. 1954. A survey of the spring chinook salmon spawning and utilization of Idaho streams. Job Completion Report, Project F-1R2. Idaho Department of Fish and Game. Boise.

Healey, M.C. 1991. Life history of chinook salmon (*Oncorhynchus tshawytscha*). In: Groot, C.; Margolis, L., eds. Pacific salmon life histories. Vancouver, BC: University of British Columbia Press: 311-393.

Hobbs, R. J.; Huenneke, L. F. 1992. Disturbance, diversity, and invasion: implications for conservation. Conservation Biology. 6(3): 324-337.

Huntington, C.W.; Nehlsen, W.; Bowers, J. 1996. A survey of healthy native stocks of anadromous salmonids in the Pacific Northwest and California. Fisheries. 21(3): 6-15.

Idaho Department of Fish and Game; Nez Perce Tribe of Idaho; Shoshone-Bannock Tribes of Fort Hall. 1990. Salmon River subbasin salmon and steelhead production plan. Boise, ID.

Idaho Department of Fish and Game. 1992. Anadromous fish management plan 1992-1996. Boise, ID: Idaho Department of Fish and Game.

King, J.; Thurow, R. 1991. Sediment monitoring techniques validation. Progress Report prepared for Idaho Department of Health and Welfare, Division of Environmental Quality. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, Idaho.

Kline, T. C. Jr.; Goering, J. J.; Mathisen, O. A.; Poe, P. H.; Parker, P. L. 1990. Recycling of elements transported upstream by runs of Pacific Salmon: I. _^15N and _^13C evidence in Sashin Creek, southeastern Alaska. Canadian Journal of Fisheries and Aquatic Sciences. 47(1): 136-144.

Knudsen, R. D.; Stapp, D.; Hackenberger, S.; Lipe, W. D.; Rossillon, M. 1982. A cultural resource reconnaissance in the Middle Fork Salmon River basin, Idaho. US Forest Service. Cultural Resource Report No. 7. Ogden, Utah.

Krohn, W. H. 1992. Sequence of habitat occupancy and abandonment: potential standards for testing habitat models. Wildlife Society Bulletin 20(4): 441-444.

Labelle, M. 1992. Straying patterns of coho salmon (*Oncorhynchus kisutch*) stocks from southeast Vancouver Island, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences. 49: 1843-1855.

Larkin, G. A.; Slaney, P. A. 1997. Implications of trends in marine-derived nutrient influx to south coastal British Columbia salmonid production. Fisheries. 22(1): 16-24.

Lee, D.; Sedell, J.; Rieman, B.; Thurow, R.; Williams, J. 1997. Broadscale assessment of aquatic species and habitats. An assessment of ecosystem components in the interior Columbia Basin and portions of the Klamath and Great basins. Volume 3, chapter 4. US Forest Service, General Technical Report PNW-GTR-405.

Lichatowich, J.A.; Mobrand, L.E. 1995. Analysis of chinook salmon in the Columbia River from an ecosystem perspective. Report for U.S. Department of Energy, Bonneville Power Administration, Contract No. DE-AM79-92BP25105, Portland, OR.

Mallet, J. 1974. Inventory of salmon and steelhead resources, habitat, use and demands. Job Performance Report. Boise, ID: Idaho Department of Fish and Game.

Marmorek, D. R.; Peters, C. N.; Parnell, I. Editors. PATH final report for fiscal year 1998. ESSA Technologies Ltd. Vancouver, BC. 263 pp.

Matthews, G. M.; Waples, R. S. 1991. Status review for Snake River spring and summer chinook salmon. NOAA Technical Memorandum NMFS F/NWC-200. National Marine Fisheries Service. Seattle.

Minshall, G. W.; Brock, J. T.; Andrews, D. A. 1981. Biological, water quality and aquatic habitat response to wildfire in the Middle Fork of the Salmon River and its tributaries. Idaho State University, Pocatello.

Meehan, W. R., ed. 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. Bethesda, MD. American Fisheries Society Special Publication 19.

Murphy, M. L. 1995. Forestry impacts on freshwater habitats and anadromous salmonids in the Pacific Northwest and Alaska: Requirements for protection and restoration. NOAA Coastal Ocean Program. Decision Analysis Series No.7. Silver Spring, MD: NOAA Coastal Ocean Office. 156 p.

National Research Council. 1996. Upstream: Salmon and society in the Pacific Northwest. Washington, DC: 39-66. Chapter 3.

Nehlsen, W.; Williams, J. E.; Lichatowich, J. A. 1991. Pacific salmon at the crossroads: Stocks at risk from California. Oregon, Idaho and Washington. Fisheries. 16(2): 4-21.

Northwest Power Planning Council. 1986. Compilation of information on salmon and steelhead losses in the Columbia River basin. Portland, OR: Columbia River Basin Fish and Wildlife Program.

Ottaway, E. M.; P. A. Carling, P. A.; Clark, A.; Reader, N. A. 1981. Observations on the structure of brown trout, *Salmo trutta* Linnaeus, redds. Journal of Fish Biology 19: 593-607.

Parkhurst, Z. E. 1950. Survey of the Columbia River and its tributaries. U.S. Department of the Interior, Fish and Wildlife Service, Spec. Sci. Rep. Fish. 39, 40, 153 p.

Quinn, T. P. 1993. A review of homing and straying of wild and hatchery produced salmon. Fisheries Research. 18: 29-44.

Raymond, H. L. 1979. Effects of dams and impoundments on migrations of juvenile chinook salmon and steelhead from the Snake River, 1966 to 1975. Transactions of the American Fisheries Society. 108: 505-29.

Reisenbichler, R. R. 1997. Genetic factors contributing to stock declines. Pages 223-244 In: Stouder, D.; Bisson, P., editors. Pacific salmon and their ecosystems. Chapman and Hall. New York.

Rieman, B. E.; McIntyre, J. D. 1993. Demographic and habitat requirements of bull trout *Salvelinus confluentus*. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, General Technical Report INT-302, Ogden, UT.

Rieman, B. E.; McIntyre, J. D. 1995. Occurrence of bull trout in naturally fragmented habitat patches of varied size. Transactions of the American Fisheries Society. 124: 285-296.

Simberloff, D. 1988. The contribution of population and community biology to conservation science. Annual Review of Ecology and Systematics 19: 473-511.

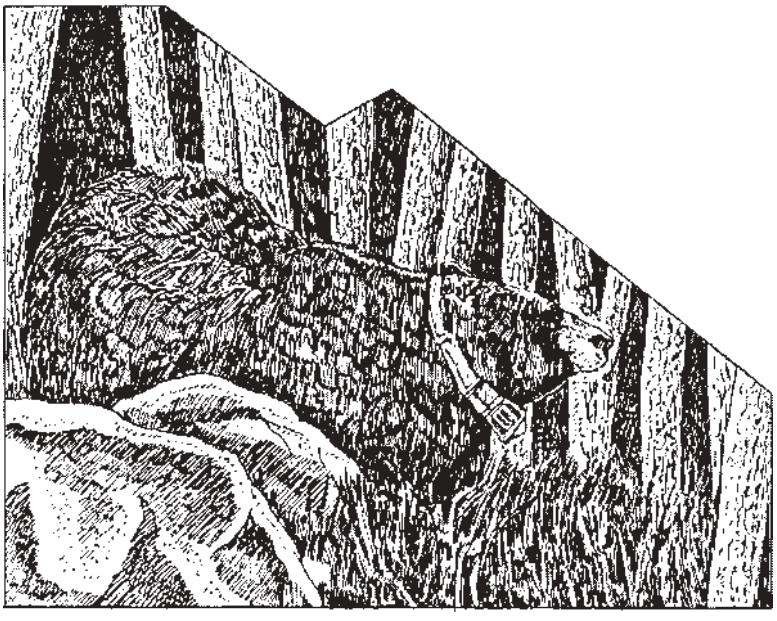
Thurow, R. 1985. Middle Fork Salmon River fisheries investigations. Job Completion Report. Federal Aid in Fish Restoration Project F-73-R-6. Idaho Department of Fish and Game, Boise.

Thurow, R. F.; Lee, D. C.; Rieman, B. E. 2000. Status and distribution of chinook salmon and steelhead in the interior Columbia River basin and portions of the Klamath River basin. In: Knudsen, E.; Steward, C.; MacDonald, D.; Williams, J.; and Reiser, D., eds. Sustainable fisheries management: Pacific salmon. Boca Raton: CRC Press: 133-160.

US Forest Service. 1998. Frank Church-River of No Return Wilderness Programmatic and operational management plans. Draft Environmental Impact Statement. US Forest Service Intermountain and Northern Regions.

Waples, R. S.; Do, C. 1994. Genetic risk associated with supplementation of Pacific salmonids: Captive broodstock programs. Canadian Journal of Fisheries and Aquatic Sciences. 51(Supplement 1): 310-329.

3. Wilderness and the Past



Paleontological Excavations in Designated Wilderness: Theory and Practice

Christopher V. Barns

Abstract—Wilderness is widely recognized as a valuable environment for scientific research, and it is generally assumed that this research will benefit the wilderness resource. But what if the research is of value only in understanding an ecosystem that has been extinct for 65 million years? What if thousands of pounds of material must be removed from the wilderness to conduct this research? In 1998, the New Mexico Museum of Natural History and Science excavated two sites within the Bisti/De-Na-Zin Wilderness—the first known paleontological excavations from a designated wilderness. This paper examines the Bureau of Land Management's analysis of the excavation proposal, including: discussions of appropriateness, determination of minimum tool, options for mitigating impacts to the wilderness resource, public outreach alternatives, and a post-excavation review of the Environmental Assessment prepared for this "ground-breaking" research.

The Bisti/De-Na-Zin Wilderness Area (B/DNZ), approximately 45,000 acres, is located in northwest New Mexico, approximately 30 air miles south of the city of Farmington and 20 air miles northwest of Chaco Culture National Historical Park.

Paleontological research has been conducted in the Bisti Badlands for almost a century. The strata exposed come from near the end of the Cretaceous Period (approximately 75 to 80 million years ago) through the beginning of the Tertiary Period (approximately 63 million years ago). Exposed on the surface of the B/DNZ, therefore, is a nearly continuous stratigraphic sequence between what is popularly known as the end of the Age of Dinosaurs and the beginning of the Age of Mammals. Almost 100 species of plants, and well over 100 species of animals (including invertebrates, fish, amphibians, reptiles, dinosaurs, and mammals) have been identified in the B/DNZ. Some of these represent either holotypes (specimens used for the original description of a species) or species found nowhere else to date.

The last comprehensive survey of this region was conducted in the mid-1970's (Kues and others 1977) and recorded over 200 paleontological sites within the Wilderness. Many additional localities have been identified through periodic monitoring. Current Bureau policy requires a permit signed by the BLM state director for the collection of any vertebrate fossils on public land. At the present, researchers from two museums hold permits for reconnaissance with limited collection (surface disturbance is limited to one square meter) within the B/DNZ. Recent surface collections have produced some remarkable finds, such as the complete *Parasaurolophus* crest (Sullivan and Williamson 1999) that was recently used to speculate on the sound of possible dinosaur "calls" (Diegert and Williamson, 1998). By BLM policy, excavation permits are considered only on a case-by-case basis.

The Role of Wilderness in the Management of Paleontological Resources

Though few areas in the current National Wilderness Preservation System have significant paleontological resources, this is expected to change as additional areas under the jurisdiction of the Bureau of Land Management are designated by Congress. Prior to 1998, no paleontological excavations are known to have been conducted in any unit of the National Wilderness Preservation System after their designation—a condition that also may be expected to change. The management of the paleontological resources within the B/DNZ has been a source of some controversy in the past. If we are to avoid such contentiousness as future units are added, a well-reasoned approach to paleontological resources in designated wilderness should be universally adopted.

Section 4 (b) of the Wilderness Act states, "Except as otherwise provided in this Act, wilderness areas shall be devoted to the public purposes of...scientific...use." Traditionally, this has been interpreted as scientific use that is dependent on wilderness conditions—usually for the benefit of the natural values of wilderness. Neither is the case in paleontological research. It does not improve the management of the wilderness (the time frames of paleontology are many orders of magnitude too coarse for day-to-day—or even century-to-century—practical application), nor does it need the conditions of wilderness to be conducted (but, rather, simply the presence of fossils). When a wilderness contains the significant fossil resource present in the B/DNZ, however, paleontological research must take place within the Wilderness or not at all.

Note, however, that this section begins with the phrase, "Except as otherwise provided in this Act...." Is paleontological research a scientific use compatible with the other provisions of the Wilderness Act?

Arguments that paleontological research may not be compatible with wilderness center on three related points of contention (Berger and others 1990): 1) consumptive or extractive scientific use of a wilderness might seriously affect undisturbed natural systems; 2) removal of paleontological resources destroys their in situ value for professionals and recreationists alike; and 3) the removal of any

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nonrenewable resource from a wilderness negatively affects wilderness character.

It is undeniable that the human removal of a nonrenewable resource constitutes an "unnatural" disturbance of the wilderness ecosystem. However, as is always the case where the wilderness resource meets human technology or anthropocentric designs, unacceptability is a matter of degree. The material removed by collection in any year is a tiny fraction of that eroded away by one day's moderate rain. In the B/DNZ, despite an average annual precipitation of approximately nine inches, the steep slopes and lack of vegetation create high rates of erosion. The isolated (five or six per decade) heavy rains in the Hunter Wash drainage often carry as much as $1\frac{1}{2}$ ton of sediment per second out of the Wilderness. True, one removal is a work of natural process, and the other is not. However, the difference is a matter of effect on the area's "wildness"; the effect on the biophysical resource is negligible.

The in situ value of a fossil is recorded at the time of its discovery. The site is noted and, if further study of the stratum is required at a later date, researchers can revisit the field. Far much more scientific information would be lost if the fossil were not removed for study. It can also be argued that far more educational information would be lost as well, as any fossil is apt to be seen by many more people in a museum setting than in a wilderness. And while the concept of removing part of a wilderness resource in order to preserve it may seem reminiscent of destroying a village in order to save it, permanently preserving fossils in the field is really the worst of both worlds: it is most certainly a constant reminder of human presence, and the addition of a foreign stabilizing chemical to halt erosion is more damaging to the natural system than simply hastening erosion by removal of the specimen.

This is far from recommending that all fossil material should be removed from wildernesses. Paleontologists at the New Mexico Museum of Natural History and Science expect that 95% of all fossil material will remain to delight and fascinate the wilderness recreationist.

Assuming research is conducted to minimize social impacts, the only lasting loss to the wilderness is something of its innately wild character—that mystical and primeval, quintessentially American, intangible quality that touches wilderness visitors and non-visitors alike. At its essence, wilderness is a place for the primitive. Justification of paleontological research in wilderness does not mean that wilderness stewardship responsibilities should be subservient to the science of paleontology. On the contrary, paleontological resources of areas such as the B/DNZ are a supplemental value of the Wilderness, and land managers must ensure that this particular community of life remains "untrammeled." As the science of paleontology serves only the human intellect, placing a wilderness resource at the mercy of this science would in fact be hobbling it to human use.

It is not the intent of this paper to downplay what could prove a very real loss, though it is perhaps important to remember that this loss of the primitive is every bit as anthropocentric as the gains in paleontology. Linda Merigliano, as reported by Parsons (1998), has framed the essential question: "How far should we deviate from 'wildness' to accommodate science?" It is an important question with no universal answer. Certainly, when the wilderness is not necessary to the science, the answer is "not at all." But this is not always the case. In order to minimize impairment to the resource of "wildness" itself, the principle of the minimum tool must be rigorously applied to all research in wildernesses. While often synonymous with the "primitive tool" that would preserve wildness resources, balance with the social and biophysical resources must also be considered when deciding upon the "minimum" tool to be used in a designated wilderness.

Therefore, paleontological research in designated Bureau of Land Management Wilderness should be subject to the following conditions:

1) Collection of any paleontological materials (not just vertebrate fossils, as is the case presently) will be permitted only with the approval of the BLM state director.
2) Approval will be granted only for scientific research or public education, and all collected material must be housed in an approved repository.
3) Necessary qualifications of the applicant will be determined by a BLM regional paleontologist in the permitting process.
4) Survey permits will be issued to monitor the paleontological resource of wilderness areas. These surveys will be used to identify new sites or sites that are at risk, and the potential for further research. It is expected that approximately 5% of the fossil material located on the surface will be collected during a survey; however, certain types of fossil material (such as teeth) will almost always be collected. Surface disturbance is limited to one square meter, with the disturbed depth no greater than 30 cm, within a 10-meter square area. Any greater disturbance would only be allowed under an excavation permit.
5) Excavation permits will be issued only on a case-by-case basis and after an Environmental Assessment determines that the proposed action will not degrade the overall wilderness character. Excavation decisions will be made following a logical and reasoned consultation between BLM wilderness specialists, BLM paleontologists, and outside experts in paleontology and wilderness management as needed to make an informed decision. Factors that will be considered in an Environmental Assessment are:
    a) rarity or significance of the species;
    b) rarity or significance of particular bone(s) found;
    c) degree of completeness (whole skeleton or element);
    d) state of preservation;
    e) potential for providing new or additional information on the species, or paleoecology;
    f) amount of disturbance to the other wilderness resources in relation to the benefit of recovery;
    g) degree to which the fossil is at risk of loss due to erosion or vandalism; and
    h) logistical difficulty in removal.
6) Any research will be conducted under the principle of using of the minimum tool. That is, "...except as necessary to meet the minimum requirements for the administration of the area for the purpose of [Wilderness],...there shall be no...use of motor vehicles, motorized equipment,...no landing of aircraft,

[and] no other form of mechanical transport....” (The Wilderness Act, Section 4 (c)). Analysis of what constitutes the “minimum tool” for any proposed action means balancing the impacts to three central, interrelated wilderness resources. First, what effect will the proposed action have on the biophysical resource, the wilderness lands designated “for preservation and protection in their natural condition” (The Act, Sec. 2 (a))? Second, what effect might it have on wilderness visitors, their experience of “solitude or a primitive and unconfined...recreation” (The Act, Sec. 2 (c))? And finally, what is its effect on the resource of wildness; i.e., what is the proposed action’s effect on the tendency of “growing mechanization [to]...modify all areas” (The Act, Sec. 2 (a)), and does the area “retain its primeval charact ill be performed to determine the approved method for removal of the specimen.

7) All collection must be conducted in a fashion that leaves the site in a substantially unnoticeable condition. This will be accomplished by a combination of backfilling, re-contouring, raking the surface, and—where necessary —revegetating the disturbed area to match the color, line, texture, and contrast of the surrounding, unexcavated land.

Practical Application of Wilderness Paleontological Excavation Theory

In early 1998, as a result of discoveries found during permitted surface reconnaissance in 1997, the first permit for a paleontological excavation in a designated wilderness was requested by the New Mexico Museum of Natural History and Science (NMMNH), under the direction of Curator of Paleontology Thomas E. Williamson. Dr. Williamson proposed to excavate three separate paleontological localities during the 1998 field season (late May through mid September):

L-3503: skull of *Pentaceratops sternbergii*
L-3506: partial skeleton of a large tyrannosaurid
L-3522: partial skeleton of a hadrosaur

The find in locality L-3503 was deemed extremely rare. *Pentaceratops sternbergii* is known only from the San Juan Basin, and only six whole or partial skulls are known to have been collected. The specimen in this locality appeared to include a nearly intact and undistorted frill margin—a feature so preserved in only one other specimen. Additional specimens of *Pentaceratops* are necessary to document variability within the taxon and its relationship to other ceratopsian dinosaurs. New specimens collected with accurate geographic and stratigraphic data will help document the spatial and temporal distribution of these animals and increase knowledge of Late Cretaceous paleoecology. In addition, NMMNH does not have a *Pentaceratops* skull on display or in its collection; therefore, the specimen in L-3503 was expected to have great public educational value.

Only two partial skeletons of tyrannosaurids, such as the one in L-3506, had been collected from the Kirtland Formation of New Mexico. It was unknown whether the L-3506 specimen was an *Albertosaurus*, “common” in the northern Rockies, or from one of two poorly known genera—*Aubysodon* or *Daspletosaurus*. The extreme rarity of this specimen made it of exceptionally high scientific value. If the specimen was found to be relatively complete, it was expected to go on display at the NMMNH, giving it great public educational value as well.

Only one relatively complete hadrosaur skeleton had been previously collected form the San Juan Basin, the holotype of *Parasaurolophus cyrtocristatus*; fewer than ten partial skeletons had been reported worldwide. L-3522 includes several disarticulated but apparently associated ribs and vertebrae. It was believed there may be other skeletal elements still buried at the site. Again it was argued that new specimens collected with accurate geographic and stratigraphic data will help document the distribution of these animals and increase knowledge of Late Cretaceous paleoecology.

Given the rarity and significance of these finds, an Environmental Assessment was prepared on the NMMNH permit. Following the reasoning outlined above, the permit was approved. Both to lessen impacts to the Wilderness and for ease of their operations, NMMNH researchers planned to camp outside the Wilderness on land managed by the State of New Mexico. In addition, BLM applied a variety of stipulations to protect wilderness resources:

> The project areas and access routes were largely unvegetated. However, to reduce the loss of plant species of special concern in the camping area, NMMNH was required to show BLM that they had obtained authorization from, and met the requirements concerning protection of vegetation of, the State of New Mexico for the camping areas.
>
> Likewise, no cultural sites were found on the surface in any of the project areas. However, without careful campsite selection, cultural sites found in the camp areas could be disturbed. To reduce the disturbance of cultural sites, NMMNH was required to show BLM that they have obtained authorization from, and met the requirements concerning protection of cultural resources of, the State of New Mexico for the camping areas. In addition, if any cultural resources were discovered during excavation, BLM required that all work at that site would stop and a Farmington District Office archaeologist be contacted for further direction.
>
> To reduce the impacts on the ferruginous hawk (*Buteo regalis*), a species easily disturbed by humans and known to nest in the B/DNZ, NMMNH was required to:
>
> a) travel at least $1\frac{1}{3}$ mile from any nest identified in the April 1998 BLM survey of project areas and access routes;
> b) camp at least $1\frac{1}{2}$ mile from any nest; and
> c) if a nest was found within $1\frac{1}{2}$ mile of any of the three fossil localities, postpone excavation at the affected localities until after the end of the ferruginous nesting season (July 15). (Note: no nest was found within this buffer zone.)
>
> NMMNH was required to conduct their research under the principle of using the minimum tool:

a) daily access was allowed only on foot;
b) all materials had to be carried in without the use of carts or other wheeled conveyances;
c) excavations were conducted by hand tools only; and
d) the use of a helicopter was considered the minimum tool for removal of these fossils.

[While a helicopter certainly is not primitive, and its use degrades the resource of wildness, other means (packing out by hand, by horse, or by wagon) were impractical due to the weight of the specimens, impractical due to the topography and geology of the localities, and would have created greater negative impacts to the biophysical resources. To minimize the social and biophysical impacts of helicopter flights, use was limited to one day for all three localities combined, and after ferruginous hawk nesting season ended. NMMNH arranged for the National Guard to fly out the field-prepared fossils.]

To reduce the effects of soil compaction or other disturbances of the natural soil regime, NMMNH was required to:

a) travel on existing cow trails or wash bottoms, where possible;
b) stockpile separately any different soil horizons encountered during excavation, and preserve the integrity of these strata during rehabilitation of each locality;
c) rehabilitate the sites to a substantially unnoticeable condition, using a combination of backfilling, re-contouring, and raking the surface to match the color, line, texture, and contrast of the surrounding, unexcavated land; and
d) remove from the wilderness (rather than bury) all fragments of plaster or other jacketing material.

Finally, NMMNH was required to provide photodocumentation of the process, from pre-excavation through post-reclamation.

The lack of adequate numbers of wilderness rangers or law enforcement personnel make the BLM ill-equipped to protect the paleontological resources of the B/DNZ given a sudden influx of fossil-hounds. Therefore, although we discussed the public relations coup of posting excavation progress reports on The Web, it was determined that neither NMMNH nor BLM would publicize the excavations in progress. Only those employees or volunteers of either organization that needed to know were informed of the exact localities or the dates of excavation. The Environmental Assessment contained no map. In any post-excavation scientific publicity, the localities were to be described in no more detail than "within the Bisti/De-Na-Zin Wilderness," and the rarity of these particular finds were to be stressed, rather than the ubiquitousness of fossils in the area. The Environmental Assessment stressed that there would be no publicity or public outreach effort made by the NMMNH or the BLM during the time of excavation. Any public affairs or environmental education initiative would be conducted after the fossils were removed from the field and the localities rehabilitated.

Post-Excavation Analysis

Summertime excavations in the high desert proved particularly arduous when conducted entirely with hand tools. As a consequence, the field work took longer than planned, and only two of the localities were collected. Though analysis is far from complete, the results from a paleontological point of view are, so far, as impressive as was hoped (Williamson and Carr 1999). The remaining fossil, L-3522, was collected in the autumn of 1999; NMMNH determined that it was in small enough pieces to be carried out by hand after field-preparation.

Photodocumentation and onsite visits six months after rehabilitation have demonstrated the remarkable capacity of this barren land to heal its visual scars given a heavy precipitation event (which arrived in October 1998). The sites are extremely difficult to find, even for one who had been there during the working period. While the dig was in progress, no ferruginous hawks were disturbed from their nests, and not one visitor happened upon the excavation team.

There was, however, a problem during the helicopter removal of the jacketed specimens. The New Mexico BLM State Office's Public Affairs department had heard about the dig and, without contacting any field personnel or their own state office wilderness coordinator, or even reading the Environmental Assessment, orchestrated a media extravaganza. The day of the removal, rather than only one National Guard helicopter showing up, a second one filled with video cameras and members of the press flew in to take spectacular footage. In addition, a third helicopter arrived, owned by a television station that wanted its own visual angle on the proceedings. Once at the staging area outside the B/DNZ, where the fossils were to be loaded on trucks for the haul to Albuquerque, the press helicopters were informed they could not land within the Wilderness. Consequently, they created no short-term biophysical resource impacts. (It is not known what long-term impacts, in the form of increased vandalism of paleontological specimens due to the additional popular exposure, might accrue, but these are probably slight.) On the day of the removal, six parties of visitors signed in at the voluntary registration box approximately four miles from the nearest locality. None mentioned the helicopters in their comments, and none complained, so perhaps the social resource impacts were entirely tolerable. But as Merigliano asks, "If visitors don't complain, is it OK?" (Parsons 1998). Certainly, the added helicopters further degraded the resource of wildness. And it was a degradation that was both entirely avoidable and seemingly incomprehensible to most of those involved.

Conclusions

The Wilderness Act states, "Except as otherwise provided in this Act, wilderness areas shall be devoted to the public purposes of...scientific...use." This traditionally has been interpreted as a support for scientific use that is dependent on wilderness conditions, and usually for the benefit of the natural values of wilderness. Paleontological research does not improve management of the wilderness (unless one considers the not-insignificant indirect benefit of this science's

popularity increasing support for wilderness protection). Nor does paleontological research require wilderness conditions. Quite the contrary, wilderness conditions make paleontological research all the more difficult. But when a wilderness happens to contain significant fossil resources, paleontological research must take place within that wilderness or not at all. Indeed, the supplemental value of its paleontological resources may be one of the reasons that particular wilderness was added to the National Wilderness Preservation System.

By applying stringent mitigating measures, very real social and biophysical impacts to wilderness by paleontological research can be minimized. Can the wilderness accept some degradation of wildness? Again, with mitigation, these impacts, though real, may be acceptable. Managers must remember that one of the greatest threats to wilderness is their tendency to rationalize tiny actions that chip away at these unique areas. Given that, paleontological research can be conducted in such a way that the gains in knowledge and support outweigh the losses.

References

Berger, A. W., W. L. Overbaugh, and G. H. Stankey. 1990. Extraction of nonrenewable resources from wilderness: a dilemma of scientific use. In: Managing America's Enduring Wilderness Resource: Proceedings of the Conference, September 11-17, 1989, Minneapolis, Minnesota. D. W. Lime, Ed. St. Paul, MN: University of Minnesota Tourism Center, Extension Service, and Agricultural Experiment Station: 292-298.

Diegert, C. F., and T. E. Williamson. 1998. A digital acoustic model of the lambeosaurine hadrosaur Parasaurolophus tubicen. Journal of Vertebrate Paleontology. 18:38A.

Kues, B. S., J. W. Froehlich, J. A. Scabbed, and S. G. Lucas. 1977. Paleontological survey, resource assessment, and mitigation plan for the Bisti-Star Lake area, northwestern New Mexico. Report on file: U.S. Bureau of Land Management, Albuquerque District Office.

Parsons, D. J. 1998. Scientific activities in wilderness. International Journal of Wilderness. 4(1):10-13.

Sullivan, R. M., and T. E. Williamson. 1999. A new skull of *Parasaurolophus* (Dinosauria: Hadrosauridae) from the Kirtland Formation of New Mexico and a revision of the genus. Albuquerque, NM: New Mexico Museum of Natural History and Science. Bulletin 15.

Williamson, T. E., and T. D. Carr. 1999. A new tyrannosaurid (Dinosauria: Theropoda) partial skeleton from the Upper Cretaceous Kirtland Formation, San Juan Basin, New Mexico. New Mexico Geology 21:42.

The Ancient Environment of the Beartooth Butte Formation (Devonian) in Wyoming and Montana: Combining Paleontological Inquiry With Federal Management Needs

Anthony R. Fiorillo

Abstract—The Beartooth Butte Formation is found in many mountain ranges throughout central Montana and northern Wyoming. This study combines a variety of geologic data to provide a clearer understanding of the fossil fauna and environmental setting of this rock unit.

Results show not all exposures of this unit are fossil-bearing and where present, faunal data vary significantly from locality to locality. Also, not all exposures of the Beartooth Butte Formation are the same age. Lastly, isotopic data show a consistent pattern of ancient salinity for this rock unit through time, suggesting a constant environmental setting for approximately 20 million years.

A casual observation of science stories across all media reveals that the public is fascinated with fossils, particularly dinosaurs (Springer 1997). These stories have served an overall purpose of raising public awareness of ancient life and ancient ecosystems. Given this latest round of enthusiastic public interest in paleontology, and the problems associated with increasing multiple-use demands on federally managed lands, it is increasingly important to document the occurrences of fossils. In addition to the public interest in fossils as an educational experience, the recent auction of a *Tyrannosaurus* (dinosaur) skeleton at a selling price in excess of eight million dollars has demonstrated that some fossils now have proven monetary value.

Federally managed lands contain some of the most important fossil-bearing rock units in the world, although historically much of the documentation and evaluation of these important units has been inconsistent, with little attention devoted to management needs. In addition to the now-established monetary value for some specimens, these fossils have proven scientific and educational worth.

Rocks of Devonian age (approximately 360-410 million years ago) have gained in scientific importance in recent years as new fossil finds around the world began to provide insight into issues of biodiversity and how vertebrate life moved onto land. The increased global interest in the Devonian Period initiated this investigation into the Devonian-aged Beartooth Butte Formation.

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The Lower Devonian Beartooth Butte Formation was discovered in northern Wyoming in the 1930s and has since been a source of vertebrate remains (Bryant 1932, 1933, 1934, 1935; Dorf 1934a). This formation was the focus of stratigraphic and paleontologic work again in the 1950s and 1960s (Denison 1966, 1968, 1970); through the course of these efforts all exposures of this rock unit had been interpreted to be the same age. Despite the geographic extent of this formation ranging from central Montana to northeastern Wyoming (Sandberg 1961), virtually all of the paleontological data collected for this rock unit are from two sites: the Beartooth Butte site or the Cottonwood Canyon site. One exception is the preliminary work at a third locality, the Half Moon Canyon site in central Montana (Fiorillo 1998). Subsequent to these early reports, additional work by others, again from only the two well-established sites, has shown that this rock unit continues to have great paleontological potential (Elliot and Ilyes 1996; Elliot and Johnson 1997).

The purpose of this report is to review the available data from these localities and two additional localities (fig. 1). More specifically, this report highlights the complex depositional history of the Lower Devonian Beartooth Butte Formation and its paleontological importance. These sites were chosen based on the presence or absence of fossil remains and the accessibility of the localities. Most of these sites are located near the boundaries of wilderness areas, or areas under study as wilderness. Lastly, this survey is being conducted to assess the paleontological importance of the rock unit and to provide federal land managers of specific forests information needed to develop a viable management plan.

Why Are Fossils Important to Management?

> "A knowledge and understanding of fossils played a crucial role in the recognition of the immense age of the Earth and in the development of evolutionary theory. In these ways paleontology has influenced fundamentally our conception of the natural world and of our own human place within it" (Rudwick 1976).

> "A century after the founding of the Republic, the United States was a leader in the scientific exploration of time..." (Lanham 1972).

For earth scientists as a whole, Zen (1993) and Moores (1996) issued a "call to arms" — a request for earth scientists

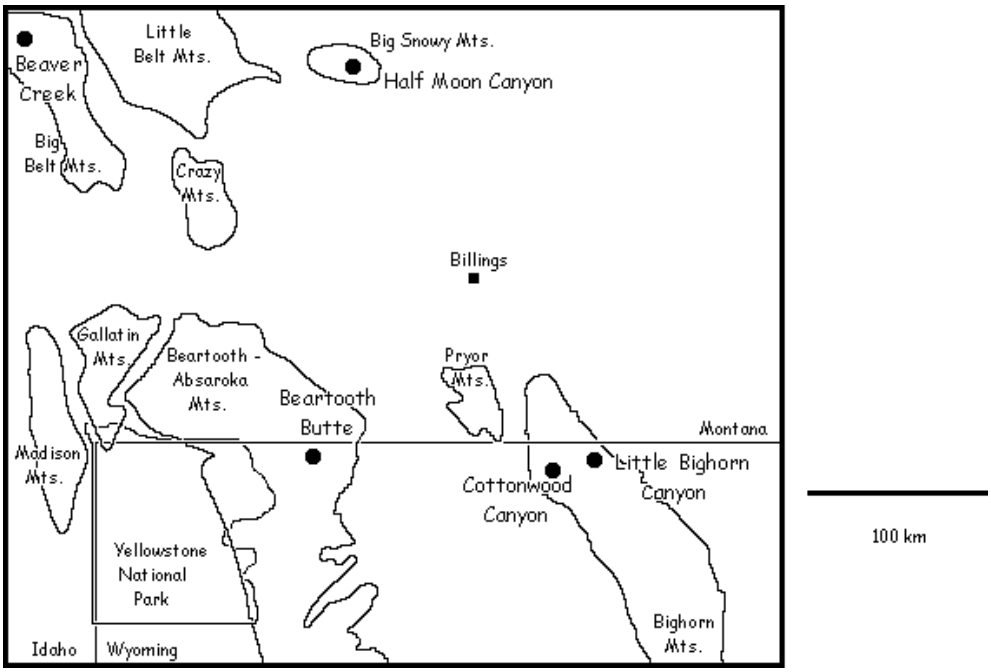

Figure 1—Map of region showing localities mentioned in this report.

to make geoscience data meaningful to the general public. Perhaps no other subdiscipline of the earth sciences can make the singular claim of already having the attention and enthusiasm of the general public, as can paleontology. Public fascination in fossils is historical, at least dating back to the earliest public displays of dinosaurs in the mid and late 19th century. In fact, based on the abundance of fossil bones discovered in the second half of the last century in the western United States, one can effectively argue that vertebrate paleontology was the means by which a young United States made its debut in the global scientific community. That this fascination with paleontology continues today is clear from the vast number of stories in the news regarding fossils. Similarly, college-level dinosaur courses are one of the two most popular earth science courses offered according to one survey (Lessem 1994), the other course being an offering on the geology of the national parks.

A potential problem is developing for federal land and resource managers concerned with the valuable paleontological resources under their care: Who should be allowed access to these resources? This development stems, in part, from increased public use of federal lands. It also is derived from the increasing tendency by some nonscientists to view fossils as commercial commodities. This tendency is evident in the recent announcements of scientifically significant fossils that are now available in auctions at substantial prices (Alvarez 1996; Browne 1996).

Increased attention to fossils by federal land and resource managers is not only timely – it is imperative given the following: the broad range of public interest in fossils, the passionate advocacy of opposed special interest groups, the appeal that such controversy has among the media (Ritter 1996), and the economic and legal impacts of an expanded array of special uses of fossil resources across the federal estate. Two previously proposed pieces of legislation, Senate Bill 3107 in the 102nd Congress (the Baucus Bill) and House Bill 2943 in the 104th Congress (the Johnson Bill), illustrate the controversy surrounding access to publicly owned fossils on federally managed lands. Despite their titles, the Vertebrate Paleontological Resources Protection Act and the Paleontology Preservation Act of 1996, respectively, these two bills represent diametrically opposed constituencies. These constituencies are, respectively, those who collect fossils for scientific and educational purposes versus those who collect fossils for monetary profit. Given the economic and legislative issues at stake, a greater awareness of fossil resources on public lands is now mandatory.

The nature of fossil resources as an educational resource makes it reasonable to develop a broad-based, flexible management plan that involves the careful identification and implementation of proper conservation of these resources. This management plan should be capable of implementation across the jurisdictional boundaries of several federal agencies. Such a plan will help satiate the public's well-developed and growing curiosity about life in the past.

The USDA Forest Service has begun an assessment of fossil resources in certain forest units with a field-level assessment on the Shoshone, Bighorn, Lewis and Clark, Helena and Gallatin National Forests, via an inter-regional partnership with the Dallas Museum of Natural History. This project, which focuses on paleontological resources, emphasizes the point that important management issues may include resources not traditionally recognized within individual federally managed land units. The common general public use of fossil resources indicates that a similar management plan can be adopted by several federal management agencies.

Geologic Background

The Beartooth Butte Formation was originally described by Dorf (1934a). While exploring the Beartooth Plateau, he noticed a reddish channel fill between the Ordovician Bighorn Dolomite and the overlying Upper Devonian Jefferson Limestone (fig. 2). Dorf, a paleobotanist, described the fossil plant material from the formation, all of which he attributed to being terrestrial (Dorf 1934b). Later work in Cottonwood Canyon of the Bighorn Mountains revealed the first evidence that this unit was more widespread than previously thought (Blackstone and McGrew 1954). Subsequent work by Sandberg (1961) demonstrated the widespread nature of the formation, though the geographic extension of the boundaries was in part based on the position of these channel-fill deposits in relation to the underlying Ordovician Bighorn Dolomite.

Bryant (1932, 1933, 1934, 1935) described in detail the original collections made of the fossil fish remains from the Beartooth Butte type section. Subsequent work by others, most notably Denison (1966, 1968, 1970) and Elliot and colleagues (Elliot and Ilyes 1996; Elliot and Johnson 1997), have demonstrated a diverse fauna for this rock unit.

The Beartooth Butte Formation has traditionally been considered to be Lower Devonian and, more specifically, Pragian in age (Johnson and others 1989). However, subsequent work by Elliot and Ilyes (1996), and Elliot and Johnson (1997) on the vertebrate material, and spore assemblages by Tanner (1983) strongly suggests that the Beartooth Butte locality and the Cottonwood Canyon locality are of two different ages. The former locality is Emsian in age, while the latter is still considered dominantly Pragian in age.

Dorf (1934a) originally considered the depositional setting for this rock unit to be an estuarine channel fill, an interpretation that remains favored by subsequent workers (Johnson and others 1988; Sandberg 1961). The data collected from these two sites, historically, are the basis for our understanding of the formation as a whole.

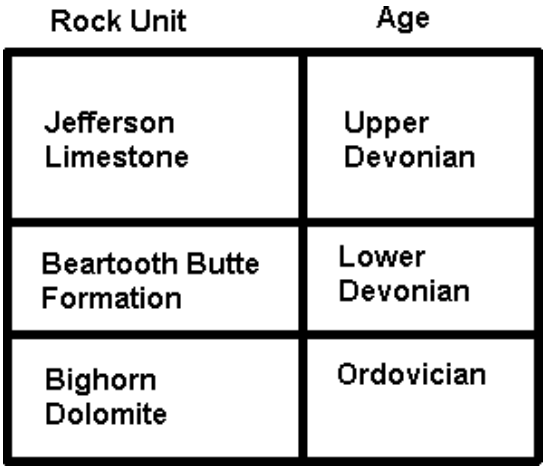

Figure 2—Generalized stratigraphic column for rocks mentioned in this report. Typically the Beartooth Butte Formation is above the Ordovician Bighorn Dolomite and below the Upper Devonian Jefferson Limestone. In some areas, the Beartooth Butte Formation is located below the Devonian Maywood Formation (not shown), which underlies the Jefferson Limestone.

Locality Geologic Section Summaries

Summaries of the fossil fish-bearing localities (fig. 1) that were examined in this study are based on the literature, direct observations in the field or through lab tests and data obtained from museum collections.

Beartooth Butte Locality

The maximum thickness of the Beartooth Butte Formation at Beartooth Butte is approximately 50 meters (Dorf 1934a). The lithology is dominantly a thinly bedded red to pinkish red to reddish maroon fine-grained limestone, or micrite. Secondarily this limestone can be yellow to yellowish gray. There is a coarse basal conglomerate for this rock unit (Dorf 1934a) and there are several lenses of conglomeratic limestone (limestone containing limestone lithic clasts) throughout the upper part of the section. Dorf (1934a) reported fish remains from all lithologies present at this site, except for the basal conglomerate and plant material from the section approximately one-quarter to two-thirds from the base of the formation.

Cottonwood Canyon Locality

The thickness of the Beartooth Butte Formation on the south wall of Cottonwood Canyon is approximately 50 meters (Sandberg 1967). Based on vertebrate biostratigraphy, Elliott and Ilyes (1996) propose that this section of the Beartooth Butte Formation is slightly older than the type section at Beartooth Butte. The rocks in the Cottonwood Canyons section are dominantly red to reddish gray, gray to yellowish gray micrites. Pebble conglomerate lenses are present but are a minor component of the section. Fossil plants occur as mats in discrete layers within gray micrites. Fossil fish dominantly occur as isolated elements (see table 2).

Half Moon Canyon Locality

The Beartooth Butte Formation, which is approximately 20 m thick, crops out on the east wall near the head of Half Moon Canyon, and is comprised of several distinct subunits (Fiorillo 1998). Capping the reddish Beartooth Butte Formation are more continuous exposures of massive gray to grayish white micritic limestone, the Upper Devonian Jefferson Formation.

Based on the presence of several different lithologies, as well as the presence of several different types of sedimentary structures, the Half Moon Canyon section of the Beartooth Butte Formation represents a complex depositional history for this sedimentary interval. By the presence of mudcracks and possible raindrop impressions, this history includes periods of subaerial exposure. Further, there are several bone-bearing horizons in this section.

Little Bighorn Canyon Locality

Sandberg (1967) determined that the Beartooth Butte Formation at this locality was less than three meters thick. The formation is a yellowish gray, fine-grained limestone or micrite.

Beaver Creek Locality

Following information from Sandberg (field notes), I was able to relocate the position of this locality (with D. Elliott/ Northern Arizona University), which is present as a relatively small outcrop visible below the base of the Maywood Formation. Sandberg reported the thickness of the formation at this locality as approximately 6.5 meters. Lithologically, this outcrop is dominantly a red to reddish gray, fine-grained limestone or micrite, with numerous yellow interbeds. There are laterally inconsistent conglomeratic lenses that are greenish in color. The middle part of this section contains simple, tubular trace fossils that are only millimeters in diameter and oriented nearly vertically.

Stable Isotope Data

Figure 3 is a plot of the stable carbon and oxygen readings obtained from the matrix surrounding the fossils. These isotopes provide a qualitative measure of the paleosalinity in which these rocks were deposited. Values of 0 or greater indicate normal marine salinities or hypersaline conditions (Faure 1986). The data in figure 3 indicate that these rocks were deposited in an environment with a freshwater component.

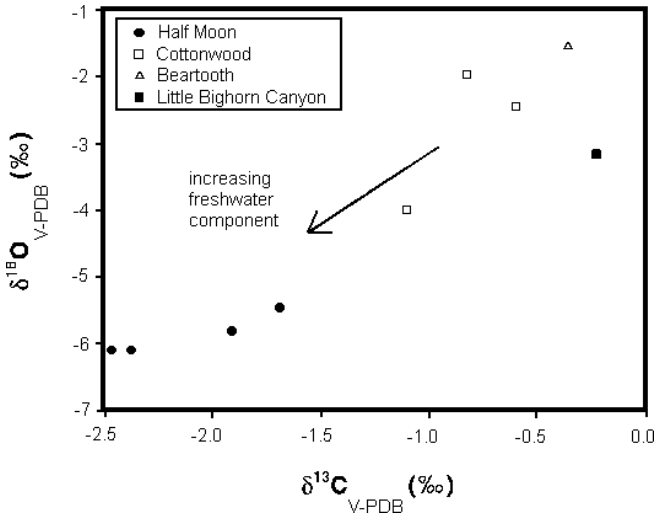

Figure 3—Plot of stable oxygen and carbon isotope data from the Half Moon Canyon, Cottonwood Canyon, Beartooth Butte, and Little Bighorn Canyon localities discussed in this report.

Vertebrate Paleontology

Table 1 is a faunal list for the sites mentioned in this report. Historically, based largely on the work of Denison (see references), the major repository for fossils from this formation has been the Field Museum of Natural History. The specimens collected by the author during this study are housed at the Dallas Museum of Natural History. The discussion for the Little Bighorn Canyon locality is based on the literature (Sandberg 1967) and the collection of material at the University of Wyoming.

The most common fish found at these localities belong to the heterostracans, that group of primitive jawless, fossil fish that have all gills open to the outside of the skeleton by a single gill opening on each side of the body (Maisey 1996). These fish tend to be no more than several centimeters in length. The second most common fish remains found at these localities belong to placoderms, jawed and armored fishes that lived only in the Devonian. These two broad taxa represent the vast majority of fishes found at these localities.

Little Bighorn Locality

The specimens housed at the University of Wyoming are mostly broken bone plates identifiable as placoderm indeterminate. Further, these plates seem to be confined to well-defined layers within the rock unit. Given the highly fragmented nature of the material in this collection, identification of many of the plates is not possible. However, two median dorsal plates are present, suggesting that the minimum number of individuals in this assemblage is two.

Beaver Creek Locality

Although remains identified as fossil fish have been reported from the Beaver Creek locality (Sandberg 1961) none were found by the author. The fish remains collected by Sandberg have been identified as *Aethaspis* and arthrodire indeterminate (written communication from Whittemore to Sandberg 1961). Given that the current location of the fish remains collected by Sandberg is unknown, I have chosen the most conservative approach to their taxonomic identification, and they are referred to in table 1 as arthrodire indeterminate.

The fossil fish yield at the Half Moon Canyon locality is low compared to the better-studied localities at Beartooth Butte and Cottonwood Canyon. However, preliminary results suggest that this site is significantly younger than the two other sites. These results are the recovery of material attributable to an antiarch placoderm and somewhat advanced osteolepid fish material (Elliott, personal communication 1998). Both of these finds suggest a Middle Devonian rather than an Early Devonian age for this outcrop. If this determination bears up with further study, the Half Moon Canyon fauna potentially offers insight into a little-known interval of time in North America.

Taphonomy

In addition to the taxonomic identity of the animals present at a fossil locality, how those animals are preserved is a source of additional insight on the paleoecology of a particular site. Data presented here offer information

Table 1—List of fossil fishes from the Beartooth Butte Formation. Genera are listed with the first letter upper case. Listed beneath each genus are the corresponding species. Data for the Beartooth Butte and Cottonwood Canyon localities are from Elliott and Ilyes (1996). Data for the Beaver Creek locality are from Sandberg (1961).

Taxon	Beartooth Butte	Cottonwood Canyon	Half Moon Canyon	Beaver Creek	Little Bighorn Canyon
Cephalaspis					
wyomingensis	X				
Oreaspis					
ampla	X				
Protaspis					
bucheri	X				
mcgrewi		X			
dorfi	X				
brevispina		X			
Cyrtaspidichthys					
ovata	X				
sculpta	X				
Cosmaspis					
transversa		X			
Lampraspis					
tuberculata		X			
Caridpeltis					
wallacii	X				
richardoni		X			
bryanti		X			
Allocryptaspis					
flabelliformis	X				
ellipticus	X				
Bryantolepis					
brachycephala	X				
cristata	X				
Anarthraspis					
chamberlini	X				
montana	X				
Onchus sp.	X				
Uranolophus					
wyomingensis	X	X			
antiarch indeter.			X		
arthrodire indeter.				X	
placoderm indeter.					X

regarding the processes responsible for formation of the fossil assemblage. The study of how fossil assemblages form is taphonomy (Efremov 1940). For example, if skeletons are preserved intact, little post-mortem alteration to the assemblage is inferred. In contrast, if the assemblage of material consists of isolated skeletal elements, a high degree of post-mortem alteration is likely. In addition to currents, in marine or aquatic environments, skeletal disarticulation can occur through a variety of means such as disintegration of a floating carcass (Elder 1985; Schafer 1972), and scavenging by carnivorous gastropods (Long and Langer 1995) or other carnivores (Schafer 1972). Therefore, one of the basic parameters used to define a fossil assemblage (Fiorillo 1991) is an examination of the completeness of the skeletons at a site. Table 2 is a summary of skeletal completeness for the sites examined, while figure 4 illustrates the various categories used in table 2. Table 3 shows the frequency of isolated elements and associated elements for two broad taxonomic groups, the heterostracan and the placoderms, at the Beartooth Butte locality.

Discussion and Summary

The depositional environment for the Beartooth Butte Formation has been interpreted as an estuarine and fluvial channel-fill (Sandberg 1961). The isotopic data presented here suggest that the localities examined in this report are more freshwater than near-shore marine.

Stable carbon and oxygen isotope data from these localities indicate a variable freshwater component during deposition. The Half Moon Canyon samples may indicate that this exposure was deposited under more fresh water conditions than either the type section at Beartooth Butte, or at the section in Cottonwood Canyon (Poulson written communication, 1998) though this difference is not easily quantifiable (fig. 3). Alternatively, the Half Moon Canyon locality may have been deposited at higher temperatures than the other localities, or perhaps even some combination of higher temperatures and fresher waters (Poulson written communication, 1998).

Trace fossils, specifically burrow structures, are present at all of the fish-bearing localities that were examined in the

Table 2—Frequency of specimens according to degrees of skeletal articulation. Isolated elements refers to individual skeletal elements, while associated skeletons refers to the occurrence of at least two elements attributable to the same individual. Partially articulated skeletons are those specimens where some elements are still articulated, and articulated skeletons are essentially intact specimens. Data based on specimens housed at the Field Museum of Natural History, the Dallas Museum of Natural History, the University of Wyoming, observations in the field. This table only includes the remains identifiable as heterostracans or placoderm, as these are the most common types of fish found in the Beartooth Butte Formation. No specimens have been found by the author, for the Beaver Creek locality either at the site or in museum collections (see Sandberg, 1961), so this locality is omitted from this table.

	Beartooth Butte	Cottonwood Canyon	Half Moon Canyon	Little Bighorn Canyon
Isolated elements	220	95	9	0
Associated skeletons	34	2	0	2
Partially articulated skeletons	3	1	0	0
Articulated skeletons	1	3	0	0

field. The study of trace fossils has a rich terminology (see Bromley 1996, for a summary), and it is beyond the scope of this paper to discuss the details of the fossil traces found at the various localities. Rather, it is appropriate to point out here that the overall morphology of the burrows at each of the sites is similar, thereby suggesting similar depositional environments at each locality. Given the different fossil fish faunas at the various localities, and particularly the probability that the Half Moon Canyon locality is significantly younger than previously realized, these traces suggest a stability to this overall depositional environment that may have extended for 20 million years.

The taphonomy of these assemblages clearly shows a preference for fossil fish material to be preserved as isolated or associated skeletal material. Articulated fossil material is exceedingly rare. Interestingly, examination of table 3 shows a greater likelihood for placoderm material to be preserved as associated material compared with elements for heterostracan skeletons. This trend is not unexpected given the more robust nature of placoderm skeletal material, despite being of the same general size as heterostracan material. Given the differences in bone density between these two types of fishes, these different patterns of preservation indicate that currents were most likely the cause of skeletal disarticulation. In other words, these data suggest that this formation preserves material that experienced skeletal disarticulation due to winnowing by currents of moderate strength, sufficient to scatter the thin bones of the skeletons of heterostracan fishes but not strong enough strength to similarly scatter the bones of all the placoderms.

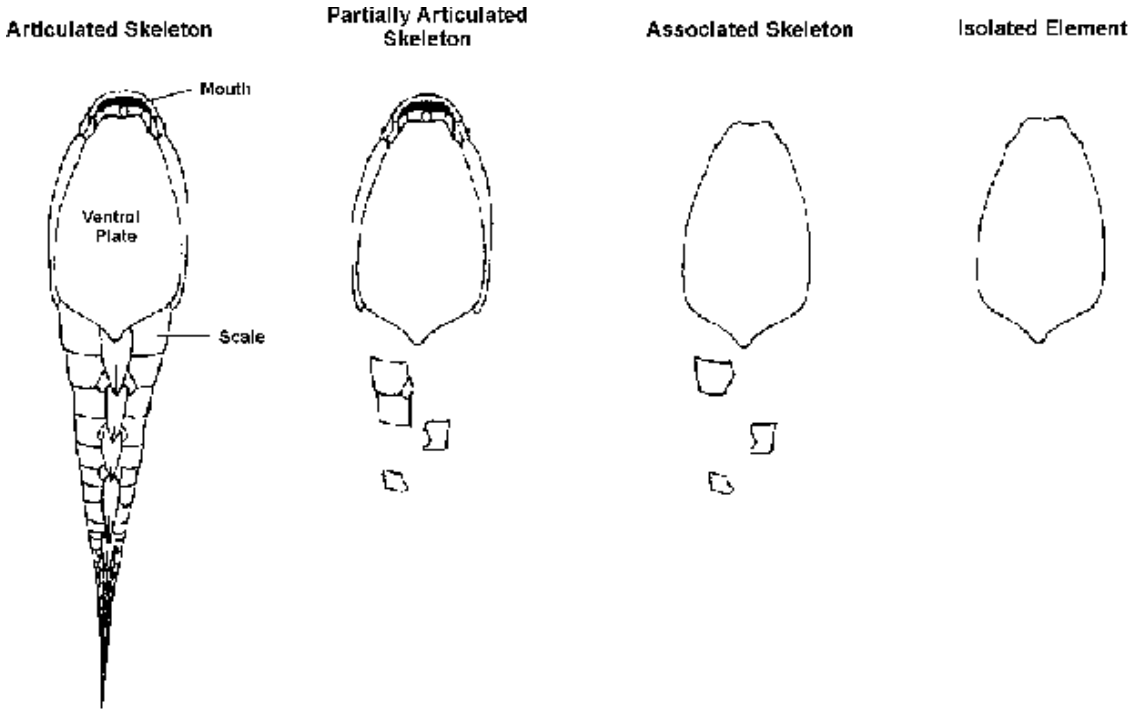

Figure 4—Generalized heterostracan skeleton, in ventral view, showing the four degrees of skeletal association used in table 2. These stages also correspond to the probable stages of skeletal disarticulation for heterostracan fishes.

Table 3—Frequency of isolated elements and associated elements for two broad taxonomic groups, the heterostracans and the placoderms, at the Beartooth Butte locality. These data were collected along a transect made along the outcrop and do not include all of the specimens listed in table 2. Notice the tendency for the bones of placoderms to stay together compared to those of heterostracans.

	Heterostraci	Placoderm
Isolated elements	67	30
Associated elements	3	31

In summary, the geologic and paleontologic data support the model that the Beartooth Butte Formation was deposited in an environment with a well-developed freshwater component. The environment probably remained stable for several million years, although the fish faunas changed during this interval. Bones accumulated in an environment that experienced moderate current flow, that disarticulated and, for some types of fish, disassociated skeletal elements.

Management Recommendations

Given the paucity of vertebrate fossil remains at the Beaver Creek locality, no special management issues need be considered here.

The abundance of fossil material at the Little Bighorn locality, based on the material already collected by the University of Wyoming, suggests that this site is worthy of more detailed scientific excavation. The inferred remote nature of the locality suggests that there are no additional management issues to be addressed at this time.

From a management perspective, the Half Moon Canyon locality is probably the most sensitive with respect to new scientific information, given the preliminary fauna recovered from this locality. However, this site is geographically remote, with difficult access. With the present state of development in the region, the site, despite its great paleontological potential, is low risk.

The Cottonwood Canyon locality has a high density of bone material and has produced large numbers of specimens. There are two components to this locality, the more commonly collected south wall locality and an apparent exposure of the rock unit on the north wall of the canyon. The north wall is nearly vertical and as such is very difficult to access. The south wall is also difficult to access, but it can be done with a great deal of effort. Unlike the other localities discussed in this report, the two components of this locality are currently on land managed by the Bureau of Land Management. No extension of this unit was found on land managed by the USDA Forest Service in this canyon. The Cottonwood Canyon localities are within a short drive of a small town (Lovell), with good road access. Therefore, though this locality is relatively close to a population center, the difficult access to reach the outcrop is a natural protective measure.

The Beartooth Butte Formation at Beartooth Butte is well-studied and abundantly fossiliferous, thereby making this locality the best known of all sites in this formation. The proximity of this locality to the existing fire tower at Clay Butte make it financially feasible to add interpretive text about the paleontology of this rock unit to the already existing interpretive displays about fire monitoring.

In summary, with respect to management issues, the geology and taphonomy of these sites indicates similar environments of deposition at all localities. However, the sites have different levels of scientific importance due to the faunal composition. Given the apparent new age considerations for the Half Moon Canyon locality, this site is the most sensitive with respect to paleontology. The Beartooth Butte locality, because of its accessibility, provides the best opportunity for a public interpretive facility.

Acknowledgments

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References

Alvarez, L. 1996. Going, going, long gone. New York Times, Dec. 15.

Blackstone, D. L.; McGrew, P. O. 1954. New occurrence of Devonian rocks in north central Wyoming. In: Richards, P. W., ed. Pryor Mountains-Northern Bighorn Basin, Montana, Billings Geological Society Guidebook, Fifth Annual Field Conference: 38-43.

Bromley, R.G. 1996. Trace fossils: biology, taphonomy and applications. 2nd ed. London, England: Chapman and Hall. 361 p.

Browne, M.W. 1996. Is a fetching T. rex worth $1 million? New York Times, Nov. 16. 9.

Bryant, W. L.1932. Lower Devonian fishes of Beartooth Butte, Wyoming. American Philosophical Society Proceedings. 71: 225-254.

Bryant, W. L. 1933. The fish fauna of Beartooth Butte, Wyoming: Part I. American Philosophical Society Proceedings. 72:285-314.

Bryant, W. L. 1934. The fish fauna of Beartooth Butte, Wyoming: Parts II and III. American Philosophical Society Proceedings. 73:127-162.

Bryant, W. L. 1935. *Cryptaspis* and other Lower Devonian fossil fishes from Beartooth Butte Formation, Wyoming. Proceedings of the American Philosophical Society. 75:111-128.

Denison, R. H. 1966. *Cardipeltis*, an Early Devonian agnathan of the Order Heterostraci. Fieldiana: Geology. 16:89-116.

Denison, R. H. 1968. Early Devonian lungfishes from Wyoming, Utah, and Idaho. Fieldiana: Geology. 17:353-413.

Denison, R. H. 1970. A revised classification of Pteraspidae with description of new forms from Wyoming. Fieldiana: Geology. 20:1-41.

Dorf, E. 1934a. Stratigraphy and paleontology of a new Devonian Formation at Beartooth Butte, Wyoming. Journal of Geology. 42:720-737.

Dorf, E. 1934b. Lower Devonian flora from Beartooth Butte, Wyoming. Geological Society of America Bulletin. 45:425-440.

Efremov, I.A. 1940. Taphonomy: new branch of paleontology. Pan-American Geologist. 74:81-93.

Elder, R.L. 1985. Principles of aquatic taphonomy with examples from the fossil record. Ph.D. dissertation, University of Michigan, Ann Arbor. 336 p.

Elliot, D. K.; Ilyes, R. R. 1996. Lower Devonian vertebrate biostratigraphy of the western United States. Modern Geology. 20:253-262.

Elliot, D. K.; Johnson, H. G. 1997. Use of vertebrates to solve biostratigraphic problems: examples from the Lower and Middle Devonian of western North America. In: Klapper, G., Murphy, M. A.; Talent, J. A. eds. Paleozoic Sequence Stratigraphy, Biostratigraphy, and Biogeography: Studies in Honor of J. Granville ("Jess") Geological Society of America Special Paper 321:179-188.

Faure, G. 1986. Principles of Isotope Geology. 2nd ed. New York; NY: John Wiley and Sons. 589 p.

Fiorillo, A.R. 1991. Taphonomy and depositional setting of Careless Creek Quarry (Judith River Formation), Wheatland County, Montana, U.S.A. Palaeogeography, Palaeoclimatology, Palaeoecology. 81:281-311.

Fiorillo, A.R. 1998. Notes on the Half Moon Canyon section of the Beartooth Butte Formation (Lower Devonian), Big Snowy Mountains, central Montana. Northwest Geology. 28:15-19.

Johnson, J. G., Sandberg, C. A.; Poole, F. G. 1988. Early and Middle Devonian paleogeography of western United States. In: McMillan, N. J.; Glass, D. J. eds. Devonian of the World: Proceedings of the Second International Symposium on the Devonian System. Canadian Society of Petroleum Geologists. 14:161-182.

Johnson, J. G.; Klapper, G.; Sandberg, C. A. 1989. Devonian eustatic events in the western United States. Geological Society of America Bulletin. 96:567-587.

Lanham, U. 1973. The Bone Hunters. Columbia University Press, New York. 285 p.

Lessem, D. 1994. How to fight dinosaur abuse. In: Rosenberg, G.D.; Wolberg, D.L. eds. Dino Fest, The Paleontological Society Special Publication 7:117-125.

Long, D.J.; Langer, M.R. 1995. Nassariid gastropods as destructive agents in preservation and fossilization of marine fishes. Experientia 51:85-89.

Maisey, J.G. 1996. Discovering fossil fishes. New York, NY: Henry Holt and Company. 223 p.

Moores, E.M. 1996. Geology and culture: a call for action (GSA Presidential Address). GSA Today. 7:7-11.

Ritter, J. 1996. Experts fear fossil free-for-all. Chicago Sun-Times, July 21. 40.

Rudwick, M.J.S. 1976. The Meaning of Fossils: episodes in the history of paleontology. 2nd edition. Chicago, IL: University of Chicago Press. 287 p.

Sandberg, C. A. 1961. Widespread Beartooth Butte Formation of Early Devonian age in Montana and Wyoming and its paleogeographic significance. Bulletin of the American Association of Petroleum Geologists. 45:1301-1309.

Sandberg, C.A. 1967. Measured sections of Devonian rocks in northern Wyoming. The Geological Survey of Wyoming Bulletin 52. 93 p.

Schafer, W. 1972. Ecology and palaeoecology of marine environments. Chicago, IL: University of Chicago Press. 568 p.

Springer, D.A. 1997. Geology in the popular press: paleontology's greatest hits. Geotimes, 42:20-23.

Tanner, W. 1983. A fossil flora from the Beartooth Butte Formation of northern Wyoming. Ph.D. dissertation. Southern Illinois University, Carbondale. 222 p.

Zen, E-. 1993. The citizen-geologist (GSA Presidential Address). GSA Today, 3:2-3.

Holocene Rain-Forest Wilderness: A Neotropical Perspective on Humans as an Exotic, Invasive Species

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Sally P. Horn

Abstract—Large areas of lowland tropical rain-forests in the neotropics have been burned over the past 6,000 years, mostly by pre-Colombian agriculturists. This paper presents additional evidence of fires and other human impacts in neotropical forests, and considers the opportunities and limitations of different approaches to determining past land-use "signatures." Knowledge of ancient land use practices may be used to advance an appreciation for the possible roles of past human disturbances in the suite of biological processes that promote diversity in lowland rain-forests. As wilderness designation becomes more common in the neotropics, an understanding of ancient land uses is essential for wilderness interpretation.

There is a widely held perspective that "the tropical rain-forest" was, until recent episodes of deforestation and fragmentation, something of a grand wilderness. Over one hundred years have passed since biologists first recognized that the presumably pristine rain-forest environments were extremely species-rich in comparison to most higher latitude environments (Darwin 1855; Wallace 1878). Naturalists working in the first half of this century focused on documenting this "extreme diversity" and proposed numerous theories to explain it. As recently as the 1970's it was a widely held belief that high species diversity in the lowland humid tropics could be attributed to the existence of relatively disturbance-free habitats in a long-stable climate. This perspective is actually the fusion of two separate theories, and the tenets of these two theories are well summarized by Pianka (1966); it subsequently achieved brief ignominy as the tropical stability theory.

Although there is still not a single, completely satisfactory theory that explains species diversity in lowland, neotropical forests, large- and small-scale natural disturbances are now well documented for rain-forests as is climatic variability (Colinvaux 1987; Hartshorn 1978). Recognition of the complex and long-term history of natural disturbances, as well as climate variability and change in lowland tropical habitats, has led to the gradual incorporation of these factors in theories to explain species diversity. This transition, however, has come about in a strange vacuum in which human populations and the effects of human populations are not usually taken into account. This is remarkable because although humans have migrated into the neotropics recently relative to other tropical regions (~14,000 – 20,000 yr. B.P.) (Bray 1986; Meggers 1995; Roosevelt and others 1996), our effects on the landscape as an exotic, invasive species have been extensive and persistent.

Surprisingly, the connection has yet to be made between the effects of humans on rain-forest and the perception of rain-forest as wilderness, even though there has been considerable research recently on ancient human populations, in rain-forests. Here we begin to examine this connection. We propose that paleoecological evidence can be used to estimate ancient land-use practices of human populations and that this information is useful in the context of wilderness perception and designation. Our approach is based on empirical data from archeological inquiries, palynological studies and soil charcoal distribution and abundance.

Soil Charcoal

Charcoal is common in the uppermost meter of soils in neotropical forests (Horn and Sanford 1992; Saldarriaga and West 1986; Sanford and others 1985; Soubiès 1979-80) as well as in sediment cores from neotropical lakes and swamps (Bush and Colinvaux 1994; Bush and others 1992; Byrne and Horn 1989; Kennedy and Horn 1997; Northrop and Horn 1996; Tsukada and Deevey 1967). In forests, soil charcoal has been observed in road and stream cuts and sampled from soil pits and with coring devices reaching to one meter deep. The usual methods for obtaining soil charcoal include: 1) obtaining intact soil cores from sequential extractions in the same borehole or 2) excavating layers of soil from small soil pits (0.25 m^2 to 1 m^2). Most of the soil-coring cylinders used for sequential sampling are small diameter, ranging from 3 cm to 8 cm. The resulting soil core or soil pit samples are soaked and sieved, and the sieved mineral soil is examined and sorted by hand for soil charcoal fragments. The charcoal is subsequently dried and weighed, with a subset used for radiocarbon dating. These procedures result in several data sets useful for interpreting the disturbance history of a site, area or region.

At the most modest level of analysis, soil charcoal data from sequential soil layers may be used to determine the presence or absence of fire at a particular site. If sampling is spatially explicit, the presence/absence of fire in a watershed or other landscape unit may be determined. In conjunction with radiocarbon dating, it is possible to develop a coarse fire

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history for a specific site or larger area. Fire history based on soil and sediment charcoal is coarse in comparison to fire history based on dendrochronology, which can provide an exact calendar year for a fire. In contrast, a radiocarbon date from a charcoal fragment always has an associated error range. The high cost of radiocarbon dating makes it impractical to determine the age of every charcoal fragment found; thus, it is quite likely that some fires will be missed by the analysis. This usually results in no better than a century-scale fire history resolution (table 1).

Soil charcoal may also be used to estimate fire recurrence for a site or larger land area. The presence of soil charcoal with widely differing radiocarbon dates from several soil depths is good evidence of repeated fires at a single sampling site (table 1). Soil charcoal of the same age taken from sampling sites over a large area (5-50 ha) is reasonable evidence for an extensive fire.

Finally, quantification of soil charcoal provides a measure of long-term carbon storage in tropical forest sites. In some areas of the Amazon, surprisingly large amounts of charcoal are present (figure 1). Although there are several problems with quantification of soil charcoal in the context of assessing wilderness status of different areas, the techniques are still useful if these problems are taken into account before sampling. Here we address the main methodological problem and comment on what we consider to be a conceptual dilemma.

Methodological difficulties are pervasive in all soil charcoal studies. All previous work with soil charcoal suffers from the uncertainty associated with identification and removal of charcoal fragments from soil samples. If the charcoal fragments are small (<0.5 mm), sorting is ineffective, and there is a likelihood that some fragments may not be removed. We and others generally use sieves with 1 mm or 2 mm openings, allowing the smallest fragments to pass; using sieves with smaller openings is not practical because of the amount of time involved. Sieve opening size most influences the quantification of soil charcoal storage, but it could also influence the quantification of timing of past fire(s), as larger sieve sizes may not allow detection of the most intense fires, which may produce predominantly smaller charcoal fragments. Of course, sieve size can also affect the recognition of the presence of past fire at a site.

Table 1—Radiocarbon dates on soil charcoal from different depths at forest sites in the north central Amazon near San Carlos de Rio Negro, Venezuela (after Saldarriaga and West 1986; dates are uncalibrated).

Depth	Site V		Site XI	
(cm)	Lab. No.	Age	Lab. No.	Age
0-10		[a]	β-9014	250 +/- 50
10-20	β-9031	480 +/- 50	β-9015	650 +/- 50
20-30	β-9032	670 +/- 50	β-9016	1560 +/- 60
30-40	β-9033	1100 +/- 50	β-9017	1700 +/- 60
40-50	β-9034	920 +/- 90	β-9018	1180 +/- 90
50-60	β-9035	1100 +/- 90	β-9019	1220 +/- 80
60-70	β-9036	6260 +/- 110	β-9020	1260 +/- 80

[a] Not recorded.

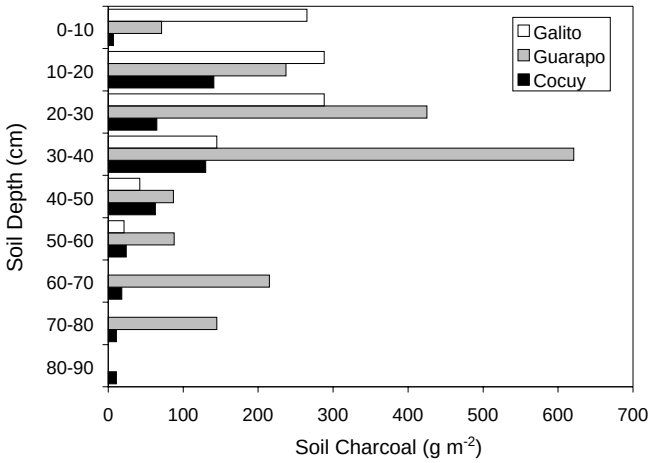

Figure 1—Mass (g m^{-2}) of soil charcoal at 10 cm depth increments for three sites in the north central Amazon along the Rio Negro. Guarapo and Galito are located in Venezuela, Cocuy in Brazil. Data at each depth is an average of three samples taken at that site. Totals are: Guarapo 1,889 g m^{-2}, Galito 760 g m^{-2} and Cucoy 470 g m^{-2}. Soil sampling depth varies as a function of depth to the plinthite (impenetrable ironstone) layer (Sanford, unpublished data).

The second issue that confounds use of soil charcoal is the issue of ignition: fire(s) of human origin versus fires resulting from nonhuman ignition sources under conditions of natural rainfall variation. Until recently, it has been difficult to accept the premise that tropical forests with >3000 mm precipitation per year could experience widespread burning originating from nonhuman ignition sources. However, observations made during the 1982-83 (Sanford and others 1985) and 1997-98 El Niño events have shown that almost every tropical rain-forest is susceptible to fire, even those with a minimal or nonexistent dry period in normal years.

Taken together, the problem of uncertainty in soil charcoal quantification and the difficulty in determining ignition sources make soil charcoal analysis an enticing but imperfect tool for estimating the extent of ancient human perturbations. Fortunately, these problems are usually bypassed by use of complementary data from archeology and palynology. Much of the early work in neotropical archeology was developed in high-elevation (Andean) or seasonally dry regions (tropical dry forests). An unintended consequence of this early focus was a misperception of extent and range of human habitation in lowland moist environments (Balee 1988). Research over the past 20 years has affirmed widespread occupation of the lowland tropics and has moved back substantially the earliest dates of human habitation (Roosevelt 1994). Archeological research has often been site-specific, focusing on an ancient village, town, or city. Archeological research across landscapes is much more limited, but it raises an interesting perspective from the point of view of wilderness. For example, the spatial extent of agriculture to support prehistoric populations throughout the lowland tropics is rarely calculated; even when it is, estimations of repeated episodes of forest conversion (at a particular site) are almost never attempted. This is an area in which the data on distribution and abundance of charcoal in soils and sediments are proving very useful.

The first charcoal evidence of prehistoric fires in neotropical forests came from analyses of microscopic charcoal particles in sediment cores from the Mayan area of southern Mexico and northern Central America (Tsukada and Deevey 1967). Macroscopic charcoal fragments have been found under mature rain-forests in Costa Rica, Panama, and several areas of the Amazon Basin. In the Amazon especially, charcoal seems to be almost ubiquitous in soils, indicating that even forests that have escaped 20th century disruption are not pristine or "virgin." The charcoal is readily datable, with reported ages ranging from 6000-250 yr. B.P. (Saldarriaga and West 1986; Sanford and others 1985; Soubiès 1979-80). Much of it may have formed as a consequence of fires set by people, but some may reflect natural ignitions (lightning or volcanism). In both cases, there may be a link with climate. When soil sieving yields pot shards along with charcoal, it argues strongly (though not exclusively) for human-set fires.

The macroscopic charcoal found in neotropical soil cores generally reflects past fires on, or very near, the site of collection. Macroscopic charcoal in lake sediments also reflects local fires, but smaller particles may reflect both local and distant burning. Charcoal in dated lake sediment cores provides stratigraphic records of changes in fire occurrence over time. These records differ from the typical situation with charcoal profiles from terrestrial soils, which may lack stratigraphy due to bioturbation and other soil processes. Abundant charcoal between dated layers in a sediment core usually signals the occurrence of a fire or fires between the bracketing dates. Extracting precise information on fire frequency can be difficult, but it is generally possible to reconstruct variation in fire activity over time. Sedimentary and soil charcoal records cannot answer all questions about past fires—but they may well comprise the only evidence available of past fires at neotropical sites where dendrochronological reconstructions of fire history are not possible.

Lake Sediments

Paleoecology refers to the science of reconstructing the structures of, and processes affecting, past biotic populations and communities. Sediment cores from natural lakes and other wetlands are particularly important data sources for the paleoecology of the period following human invasion of the New World tropics. The pollen grains, charcoal fragments and other plant microfossils that accumulate and persist in sediments, together with characteristics of the sediment matrix, reveal characteristics of past vegetation, climate, fire regime and other environmental factors, including those related to human use of landscapes.

In this section, we describe some of the methods, opportunities, and limitations of paleoecological research from sediments, as applied to understanding the human history of wilderness areas. Lake sediment cores for paleoecological study are recovered from anchored platforms constructed of rubber rafts, inner tubes or other floats, using a variety of coring devices. Most sediment corers are engineered such that sediment enters the core barrel as it is pushed downward through a particular section of the profile, from the sediment/water interface to a depth of 1 m sub-bottom, or from 1 m sub-bottom to 2 m sub-bottom. The corer is attached to drill rods, which are pushed down manually, in some cases via hammering. A piston controls the depth at which sediment begins to enter the core barrel and provides sufficient suction to keep the sediment from falling out of the barrel when raised back to the coring platform. Cores are recovered as strings of core sections from the same hole, often in 1 m increments. Swamps and bogs without deep standing water can be sampled using a greater variety of coring devices.

Cores of sediment are either extruded in the field and wrapped in plastic and foil, or are returned to the lab still encased in the original core barrel (in which case a new core barrel is used for each core section). Cores are sampled in the laboratory to provide material for radiocarbon dating. Accelerator-mass-spectrometry (AMS) radiocarbon dating makes it possible to date individual, small organic macrofossils, such as leaves or charcoal particles. AMS dating of small, potentially identifiable organic macrofossils not only provides precise dating, it also provides an opportunity to tightly constrain events of potential interest (for example, a time when a particular tree species grew close enough to a core site to deposit a distinctive leaf, or a time when the watershed burned, producing macroscopic charcoal deposited at the core site.)

Pollen grains and other acid-resistant microfossils are extracted from sediment cores using techniques of chemical and mechanical separation originally developed in Europe. Although wind-pollination is rare in the tropics, pollen production is high enough and dispersal is efficient enough to result in the deposition of pollen-rich mud in most natural basins. Pollen types are distinct and can be identified by comparison to reference material prepared from herbarium sheets. Interpretations of pollen spectra (samples) are facilitated by the study of modern pollen deposition in areas of known vegetation and human disturbance regimes (Bush 1991; Rodgers and Horn 1996).

Pollen preparations often contain microscopic charcoal, which is resistant to the chemicals used to extract pollen grains. Other microfossils, such as phytoliths and diatoms, dissolve during the normal pollen processing routine but can be concentrated using other procedures. Phytoliths (silica bodies from plants) can supplement pollen evidence of the past distribution of plants, including crop plants (Piperno 1988). Siliceous valves of diatoms (unicellular algae) or the remains of cladocera (small crustaceans) preserved in sediments can provide information on limnological conditions, which may in part reflect land use (Birks and Birks 1980). The mineralogy, chemistry and rate of deposition of the sediments can provide information on soil erosion associated with past human use of watersheds (Dunning and others 1998).

Paleoecological evidence of past human interaction with tropical forests began to be recovered in the 1940's, when Edward Deevey and collaborators cored lakes in Central Mexico and later in the Mayan area of southern Mexico and adjacent northern Central America (Tsukada and Deevey 1967). The pioneering efforts of Deevey and collaborators have been followed by others, resulting in the development of numerous paleoecological records, many of which are relevant to understanding neotropical land use history. Each site investigated gives a slightly different picture, but a common pattern is one in which pollen spectra suggest an interval of forest clearance and agriculture (low tree pollen

percentages, high values for grasses and composites, and the presence of maize or corn pollen), followed by abandonment or lessening of agricultural activity and regrowth of the forest (rise in tree pollen). Some pollen records begin with higher tree pollen percentages, suggesting initially forested surroundings; some show multiple peaks in agricultural indicators and/or evidence of more recent (European) forest clearance. The pollen spectra at different depths in sediment cores often contain microscopic charcoal, defined as those pieces too small to be seen with the naked eye. The abundance of microscopic charcoal in sediment cores often appears to correlate with pollen indicators of agricultural activity, although the source area for the smallest charcoal fragments may be larger than the source area for the pollen grains (Clark 1988).

Neotropical Wilderness in the Context of Paleoecology

What we can learn from paleoecology about human history of neotropical wilderness is limited by site availability, by the nature of sediment records and the microfossils they contain and by our incomplete (but growing) knowledge of the taphonomic processes that affect the deposition and preservation of different microfossils. Often, however, the data gleaned from paleoecological analyses provide some of the only evidence available to answer questions about past human land use. That is, the data source is imperfect but has few competitors. Here we discuss in more specific terms what we can learn from paleoecological analyses.

Pollen grains and charcoal fragments, the two most commonly investigated paleoecological indicators in the neotropics, usually provide a basis for determining:

1.) Whether fires occurred.
2.) Fire recurrence.
3.) Spatial extent of fires.
4.) Plant taxa that were present in the past.
5.) Whether forests were cleared.
6.) Whether maize (corn) was cultivated.

Soil charcoal has been used to address the first three and sediment analysis for all but #3, which requires the rare situation of abundantly distributed lakes and swamps to preserve samples across a landscape (Clark and Robinson 1993). The presence of soil charcoal is direct evidence that the vegetation of that site has burned sometime in the past. Several layers of soil charcoal at different depths provide reasonable evidence that several fires have occurred, and a coarse fire frequency may be determined by radiocarbon-dating charcoal pieces from the different layers. Estimating the spatial extent of ancient rain-forest fires requires sampling large areas (1-100 ha) and, if several layers of charcoal are present, resolution of the timing of the fires. An important condition for these analyses is the presence of nonalluvial soils. The potential for fluvial deposition makes soil charcoal analysis unreliable as an indicator of local fires on alluvial soils.

Although it is intriguing to infer human alteration of almost all of the lowland tropics during the late Holocene (Kershaw and others 1997) not enough soil charcoal data have been coordinated with archeological and palynological analyses to infer ubiquitous human perturbation. The issue of human vs. natural ignition sources remains unresolved for most areas of the neotropics and will remain so until more detailed paleoclimatic reconstructions are available. The ignition source of past fires may become an important issue as our understanding of the biogeography of tropical species diversity increases.

An interesting issue that revolves around ancient human land use practices is the extent to which species distributions have been modified. For example, both Mayan and Amazon cultures have distributed plant species that have become resident outside of their original areas of distribution (Gomez-Pompa and Kaus 1990; Smith 1980). In areas that have been most intensively used by ancient human populations, soil charcoal is present at sites where soils have been altered to Anthrosols. Although these are relatively small areas (probably sites that were repeatedly occupied as village sites), the changes in soil texture and chemistry result in a striking "landscape signature" with potentially long-lasting effects on plant and animal species composition.

Analysis of lake sediments adds a more precise dimension to understanding human signatures on the landscape. The presence of pollen of a particular plant species reveals that the plant was present at the time the sediments were deposited. This information is critical to documenting the structure and nature of prior plant populations and communities at wilderness sites. However, the preponderance of animal pollination in neotropical forests results in a large number of what Bush and others (1992) have termed "silent taxa" (present in the forest, but not present as pollen.) For these taxa, absence of evidence cannot be taken as evidence of absence. Outside of the neotropics, where more plants are wind-pollinated, such reasoning might be acceptable. For example, if chestnut pollen is not present in a 5,000-year-old sediment sample from Tennessee, one can be reasonably certain that the plant didn't grow in the area. This kind of reasoning is not valid for many neotropical taxa.

A related limitation is that while the presence of a pollen type documents the past occurrence of the plant, it does not indicate an exact location where the plant was growing. Pioneering work by Bush and Rivera (1998) has provided a basis for interpreting how far from the sampling site the responsible plant may have been located (which varies by species). Examining samples from multiple core sites all representing the same time period would also help to constrain the past geography of plant populations.

A number of pollen types potentially signal human disturbance of neotropical rain-forests, but distinguishing cultural impacts on forests from natural forest dynamics can be difficult. The weedy secondary tree *Cecropia* readily colonizes large canopy gaps, and increases in the abundance of *Cecropia* pollen in a sediment record could reflect initial forest succession on abandoned plots in areas of active field rotation, or along field margins. However, natural gap-forming processes, such as landslides on steep slopes or along streams, could also increase suitable habitat for *Cecropia* trees and the importance of their pollen grains in sediment records. The same situation applies to the pollen of weedy herbaceous families, such as grasses and composites. We expect these pollen types to be more abundant during periods of forest clearance and more agricultural activity,

but other environmental processes could also lead to increased grass and composite percentages.

Less ambiguous evidence of prehistoric crop cultivation is provided by the pollen of crop plants. By far the most important such taxon in the pollen record is *Zea mays* (maize or corn). Maize pollen (figure 2) is wind pollinated, but the pollen grains are large and tend to settle out close to the parent plants (Raynor and others 1972). As a result, the presence of maize pollen is an excellent indicator of local maize cultivation. The presence of maize pollen in swamp sediments from the La Selva Biological Station, Costa Rica, documents the cultivation of maize pollen as recently as 700-300 years ago in one part of the reserve (Kennedy and Horn 1997), and as early as 2,700 years ago in another part of the reserve (Horn and Kennedy, in press).

In summary, analyses of ancient pollen grains, and soil and sedimentary charcoal, provide a useful, complimentary set of tools that are gradually coming to be applied to the determination of human land use signatures at landscape and large scales. Sediment analysis is somewhat limited by the potentially large sizes of the source areas for pollen and the smallest microscopic charcoal, as well as the resolution of pollen taxa. Soil charcoal analysis is limited by the difficulty of recovering the smallest size fractions, and by the inability to distinguish human and natural ignitions from charcoal alone. However, we are seeing a continued refinement and wider and concurrent application of soil and sediment analysis to describe the land-use signatures that have been created by hundreds of generations of agriculturists in neotropical rain-forests.

Implications

"…and you lived in the wilderness a long time." Joshua 24:7

Ultimately, for wilderness, does it matter when and where human populations lived in, burned and otherwise modified tropical rain-forests? Should we still propose wilderness designation for areas that have clear evidence of pre-Columbian human perturbations?

In North America, managers and scientists have debated this issue and will continue to do so. The concept of wilderness has evolved from the perception of a pristine element of the landscape, a place where *Homo sapiens* is and always has been an ephemeral visitor, to the perception of wilderness as an area that is managed to remain wild (Foreman, in press). Given the "manage for wildness" mandate, lowland tropical forests that were once corn fields could well fit into wilderness designation, and it may be more useful to determine the time since last use, or more importantly, the degree to which the 300-year-old forest that has grown back from a corn field now resembles the nearby 1,000-year-old forest. Perhaps knowledge of ancient land-use practices in areas that now become designated as wilderness can foster appreciation of the possible role of human disturbance in the suite of biological processes that promote diversity in lowland rain-forests. Since humans invaded the neotropics 14 millennia ago, our presence has resulted in a series of disturbances ranging from hunting (and perhaps overhunting) to intensive agricultural activities that required forest removal during the past four to eight millennia.

In the lowland tropics, where massive deforestation is occurring at rates much higher than ever occurred in the past, this issue of previous human occupation and disturbance is increasingly important. Most neotropical national parks and forest reserves have been established since 1970. In many cases, park establishment and management followed (more or less) the U.S. model of dedicating areas of particular natural beauty that were also thought to be pristine. In North America, most now recognize that pristine is an add-on component to wilderness, but not a crucial criterion for wilderness designation. In the tropics, many are just coming to appreciate how scarce truly "pristine areas" are. Eventually, as Latin American land-managers designate wilderness areas, it will become important to appreciate wilderness in its broadest sense and to appreciate the truly special category of pristine wilderness—if such places still exist.

In a very real sense, the issue of past human habitation is linked with present-day management controversies. If people formerly lived on the land that we now classify as wilderness, it seems easier to justify present-day human activities to manage wilderness. Human endeavors have left a legacy of landscape signatures that slowly become erased with time. Signatures such as changes in soil chemistry, maize pollen in swamp sediments and charcoal fragments in tropical soils slowly become blurred over centuries and millennia, but they are evidence for past human management activities in areas that we could now designate as wild.

Figure 2—A pollen grain of maize (*Zea mays* L.) from the Machita swamp in the old growth, lowland rain-forest at the La Selva Biological Station, Costa Rica. The grain is about 70 um in maximum dimension. The presence of prehistoric maize pollen in swamps at this research station indicates that this "wilderness" was managed by prehistoric inhabitants. (Photo by Karen Burhenn.)

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References

Balee, W. 1988. The culture of Amazonian forests. Advances in Economic Botany. 7:121-133.

Birks, H. J. B. and Birks, H. H. 1980. Quaternary paleoecology. Baltimore, MD: University Park Press.

Bray, W. 1986. Finding the earliest Americans. Nature. 321:726.

Bush, M. B. 1991. Modern pollen-rain data from South and Central America: a test of the feasibility of fine-resolution lowland tropical palynology. The Holocene. 1(2): 162-167.

Bush, M. B.; Piperno, D. R.; Colinvaux, P. A.; De Oliveira, P. E.; Krissek, L. A.; Miller, M. C.; and Rowe, W. E; 1992. A 14,300-yr paleoecological profile of a lowland tropical lake in Panama. Ecological Monographs. 62(2): 251-275.

Bush, M. B. and Colinvaux, P. A. 1994 Tropical forest disturbance: paleoecological records from Darien, Panama. Ecology. 75(6): 1761-1768.

Bush, M. B. and Rivera, R. 1998. Pollen dispersal and representation in a neotropical rain forest. Global Ecology and Biogeography Letters. 7: 379-392.

Byrne, R. and Horn, S. P. 1989. Prehistoric agriculture and forest clearance in the Sierra de los Tuxtlas, Veracruz, Mexico. Palynology. 13: 181-193.

Clark, J. S. 1988. Particle motion and the theory of stratigraphic charcoal analysis: source area, transport, deposition and sampling. Quaternary Research. 30: 67-80.

Clark, J. S. and Robinson, J. 1993. Paleoecology of fire. In: Crutzen, P. J. and Goldammer, J. G., eds. Fire in the Environment: The Ecological, Atmospheric and Climatic Importance of Vegetation Fires. Chichester, UK: John Wiley and Sons: 194-214.

Colinvaux, P. A. 1989. Amazon diversity in light of the paleoecological record. Quaternary Science Reviews. 6: 93-114.

Darwin, C. 1855. Journal of Researches into the Natural History and Geology of the Countries Visited During the Voyage of the H.M.S. Beagle Round the World. New York, NY: Appleton. 524 p.

Dunning, N.; Rue, D. J.; Beach, T.; Covich, A.; and Traverse, A. 1998. Human-environment interaction in a tropical watershed: the paleoecology of Laguna Tamarindito, El Peten, Guatemala. Journal of Field Archaeology. 25(2): 139-151.

Foreman, D. In press. The real wilderness idea. In: Cole, David N.; McCool, Stephen F.; Freimund, Wayne A.; O'Loughlin, Jennifer, comps. Wilderness science in a time of change conference—Volume 1: Changing perspectives and future directions; 1999 May 23-27; Missoula, MT. Proceedings RMRS-P-15-VOL-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Gomez-Pompa, A.; and Kaus, A. 1990. Traditional Management of Mexican Forests. In: Anderson, A. B. Alternatives to Deforestation. New York, NY: Columbia University Press: 45-64.

Hartshorn, G. S. 1978. Tree falls and tropical forest dynamics. In: Tomlinson, P. B. and Zimmermann M. H., ed. Tropical trees as living systems. Cambridge, UK: Cambridge University Press: 617-638.

Horn, S. P. and Sanford Jr., R. L. 1992. Holocene fires in Costa Rica. Biotropica. 24: 354-361.

Horn, S. P. and Kennedy, L. M. In press. Pollen evidence of maize cultivation 2700 years ago at the La Selva Biological Station, Costa Rica. Biotropica.

Kennedy, L. M. and Horn, S. P. 1997. Prehistoric maize cultivation at the La Selva Biological Station. Biotropica. 29(3): 368-370.

Kershaw, A. P.; Bush, M. B.; Hope, G. S.; Weiss, K.-F.; Goldammer, J. G.; Sanford Jr, R. L. 1997. The contribution of humans to past biomass burning in the tropics. In Clark, J. S.; Cachier, H.; Goldammer, J. G.; and Stocks, B.; eds. Sediment Records of Biomass Burning and Global Change. Berlin, Germany: Springer-Verlag: 413-442.

Pianka, E. R. 1966. Latitudinal gradients in species diversity: a review of concepts. American Naturalist. 100:33-46.

Meggers, B. J.; 1995. Judging the future by the past: The impact of environmental instability on prehistoric Amazonian populations. In Sponsel, L. E.; ed. Indigenous peoples of the future of Amazonia: An ecological anthropology of an endangered world. Tuscon, Arizona: University of Arizona Press: 15-43.

Northrop, L. A.; and Horn, S.P. 1996. PreColumbian agriculture and forest disturbance in Costa Rica: paleoecological evidence from two rainforest lakes. The Holocene. 6: 289-299.

Piperno, D. R. 1988. Phytolith analysis: an archaeological and geological perspective. San Diego, CA: Academic Press. 280 p.

Raynor, G. S.; Ogden, E. C.; and Hayes, J. V. 1972. Dispersion and deposition of corn pollen from experimental sources. Agronomy Journal. 64: 420-427.

Rodgers III, J. C. and Horn S. P. 1996. Modern pollen spectra from Costa Rica. Palaeogeography, Palaeoclimatology, and Palaeoecology. 124: 53-71.

Roosevelt, A. C. (ed.) 1994. Amazonian Indians from Prehistory to the Present: Anthropological Perspectives. Tuscon, AZ: University of Arizona Press.

Roosevelt, A. C.; Lima da Costa, C.; Lopes Machado, C.; Michab, M.; Mercier, N.; Valladas, H.; Feathers, J.; Barnett, M.; Imazio da Silveira, M; Henderson, A.; Silva, J.; Chernoff, B.; Reese, D. S.; Holman, J. A.; Toth, N.; and Schick, K. 1996. Paleoindian cave dwellers in the Amazon: the peopling of the Americas. Science. 272: 373-384.

Saldarriaga, J. G.; and West, D. C. 1986. Holocene fires in the northern Amazon basin. Quaternary Research. 26: 358-366.

Sanford, Jr., R. L.; Saldarriaga, J.; Clark, K.; Uhl, C.; and Herrera R. 1985. Amazon rain-forest fires. Science. 227: 53-55.

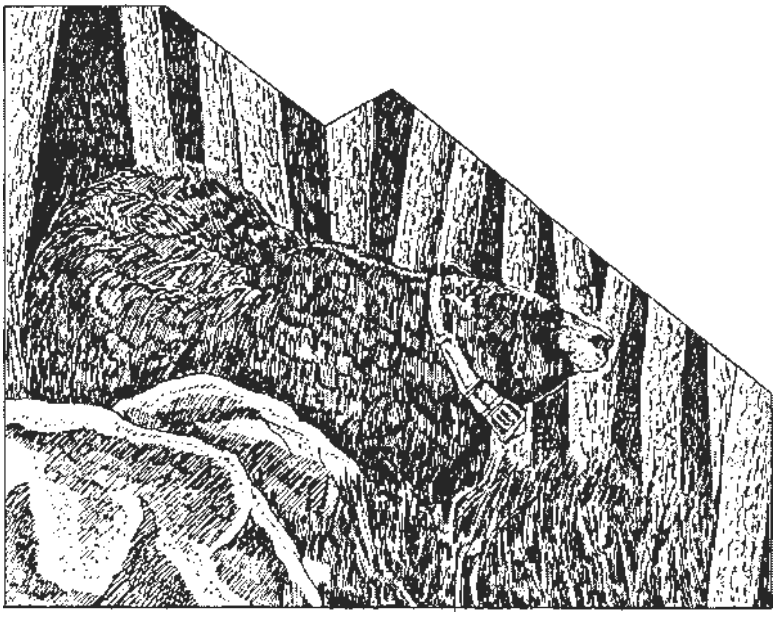
Smith, N. J. 1980. Anthrosols and human carrying capacity in Amazonia. 1980 Annals of the American Association of Geographers. 70(4): 553-566.

Soubiés, F. 1979-80. Existence d'une phase sèche en Amazonie Brésilienne datée par la présence de charbons dans les sols (6.000-3.000 ans B.P.). Cah. ORSTOM Ser. Geol. 11: 133-148.

Tsukada, M. and Deevey, Jr., E. S. 1967. Pollen analysis from four lakes in the southern Maya area of Guatemala and El Salvador. In: Cushing, E. J. and Wright, H.E., eds., Quaternary Paleoecology. Proceedings of the VII Congress of the International Association for Quaternary Research. New Haven, CT: Yale University Press: 303-331.

Wallace, A. R. 1878. Tropical Nature, and Other Essays. London: Macmillian and Co. 372 p.

4. Wilderness and People



Wilderness: A Place for Ethical Inquiry

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Abstract—This paper describes an unusual use of wilderness for inquiry: a college course in ethics which includes a 10 day wilderness trip as an integral part of the course. Through a combination of traditional classroom learning and experiential education students are encouraged to develop a new vision of ethics – ethics as a kind of wisdom about how to live a full and richly satisfying life. Students come to rely on the awe inspiring sublimity and beauty found in the San Juan mountains of southwestern Colorado to explore first-hand what it means to live as an ethical community in the wilderness.

The course "Ethics as Wisdom" is offered during summer term at a liberal arts college in northern New York State. The first eight to ten days of the course are taught on campus in a classroom setting. It is highly intensive: We meet six hours each day, and students have reading and writing assignments on top of that. Of course, we don't try to conduct intensive discussions the entire time. On a typical day, two hours might be devoted to intensive discussion of readings on ethical theory, an hour would go to watching a video, another hour or two would be devoted to discussing the video, and an hour would be devoted to planning our wilderness trip. All of these elements are related, since the video provides content for ethical reflection, and we approach the trip planning as an opportunity to practice foresight and forethought, and to discuss their role in a well-lived life.

Course Overview

After the intensive on-campus segment, course participants fly to Durango, Colorado, and we spend eight to ten days in the Weminuche Wilderness of the San Juan Mountains. This trip is the culmination of the course, after which students write a take-home final exam, explaining what they learned about ethics from the course. The role of this wilderness segment of the course is the main subject of the rest of our paper.

Obviously, the course is an exercise in experiential education. It makes no attempt to compete with a regular semester course in breadth of coverage. It would not be a good substitute for a regular classroom course in ethical theory or for a student preparing to take a standardized exam on ethics. Instead, its purpose is to have a deep impact on the student's thinking about a limited range of ethical topics.

In teaching this course, we make certain assumptions. One is that many of our students think of ethics and morality as a set of prohibitions imposed on the individual from without, prohibitions that prevent one from doing what one truly wants. The key ideas here are that ethics is primarily a set of rules, that it is imposed on the individual by some alien authority, and that it results in unwelcome and restrictive prohibitions.

We try to bring students to see ethics quite differently in our course. In the new vision, the key ideas are that ethics is not primarily external rules but internal know-how, that it comes not from without but from one's own wisdom, and that feeling ethical living as a series of limitations is largely a result of failing to fully understand the relevant issues.

We present ethics as a kind of wisdom, wisdom about how to live so that one's life is as rich, as deep, as satisfying as possible. As such, far from being an alien imposition, ethical knowledge is the most important kind of knowledge a person can have. Ethics, we teach, is not something handed down from above, but a necessity that grows out of the human condition. We have needs – not only for food and shelter, but also for security, love, approval, stimulation, activity, meaning – that cannot be adequately satisfied in isolation. The nonhuman universe may at times present a face of indifference and even hostility. And yet, this same universe is our home, and we are not ill adapted to live here. With a bit of luck, and a measure of wisdom, we can satisfy our needs, richly, and we cannot merely live, but live well.

Because we are social beings, because our lives necessarily at some points and normally most of the time involve life in a group, a great deal of ethics concerns interactions with others. This, however, is the endpoint, not the beginning, a consequence of the importance of others in a well-lived life, not the whole meaning of ethics.

Our course, then, is intended primarily to convey a vision of ethics and its importance. We try to shift our students' viewpoints and to inspire them to begin to search on their own for wisdom about how to live. "On their own" does not mean without guidance from the great store of ethical wisdom to be found in the artists, philosophers and religious thinkers of our world. It means, rather, that we hope that students will be inspired, having understood the importance of ethics, to search in every source, living or dead, to learn better how to live.

We do not try to teach specific rules or guidelines. Students take away very little from our course about how to behave that they did not bring with them. Our belief is that learning how to live well, how to contribute to the well-lived life for others, is a life-long project. What we hope is not to telescope that project into a few short weeks, but rather to impress upon our students the dignity and value of undertaking such a project with dedication, attention and energy.

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Underlying Conception of Course

Since the object of ethics is living well, rules stand to true ethics as a textbook stands to good flyfishing. What is in the book may be perfectly true, but what matters is what one can actually embody in one's fishing. So with ethics, rules are fine so far as they go, but the trick is to embody them spontaneously, and with good judgment on all the occasions when they are called for. This is an art, not a science. It might be described as the difference between "knowing that" (the rules) and "knowing how" (in actual conduct). It is important, of course, to know that you shouldn't harbor a grudge, but this is only the starting point, for one must also know how to avoid doing this in all the many ways it is possible. This, then, is one major reason why our course must have an experiential component. One acquires skill, not from a book, but from practice, and so to the degree that ethics involves skill, students must practice. Our short course doesn't, of course, give them a great deal of practice, but still it is essential that students go beyond mere classroom memorizing or theorizing. However tentatively, they must try to live by the light of what they are learning, for what they are learning is nothing unless it is lived.

So the purpose of our course is to convey to students this perspective, and thereby to motivate them to begin their own lifelong search for ethical wisdom. We think that experiential education is essential for this purpose. Arguably, information and purely intellectual skills are best taught in the traditional classroom setting. So the traditional classroom approach—suitably enriched by art (videos) and practice (the planning) – is important. But to reach our students in a way that is likely to have a lasting effect on their motivation, and to help them understand fully how ethics is practical wisdom rather than a body of abstract rules, we need the power of experience. This is the reason for the field trip.

Importance of the Wilderness Setting

It would be natural – one might even expect – that we would teach environmental ethics using a wilderness trip as a vehicle. And to a small degree we do this. Naturally, we teach students to travel lightly and with minimal impact, and naturally conversation turns at times to the disturbing and ambivalent relationship we moderns have with the natural world.

This isn't, however, the main focus of course. Our subject is the more encompassing one, ethics, of which environmental ethics is a part. So the question is, why? What are the qualities of the wild setting that enhance our ability to teach ethics? Why do we think wilderness invites students to explore more deeply than they would in a classroom the way they have, do and shall live their lives? The answer to these questions can be organized under four headings: The Self, Life With Others, The Sublime and Beauty.

The Self

The quality of one's life depends, of course, on a great many outside things, some of them wholly outside one's control. Pure luck plays a big part, as do the people one interacts with and the nature of one's society. Still, there is one constant we all have to live with and through – ourselves. With enough malevolence or incompetence, a person can even turn heaven into hell: In fact, some might describe that as a great part of the human story.

We can tell students this in our classroom. We can illustrate it with films and stories. We can arrange discussions in ways intended to make it more personal and more memorable. But the beauty of backpacking together in the wilderness is that it gives us constant little reminders and illustrations of how one's happiness depends on one's self. A sleeping bag badly stowed can mean a wet, cold night with no one to blame but oneself. A harsh word can mean a conflict everyone sees, and an occasion for self-examination one can't escape. A wrong turn on the trail can spell the difference between an easy hike and an exhausting one. On a wilderness trip, the reality that happiness depends on how a person lives is all there, all the time, and all that most instructors have to do is frame it so it gets noticed.

It would be a mistake, however, to think, that all the lessons are negative. On the other side, our students will typically come away from this trip with a new or at least renewed sense of their own capability and competence. These are young people, and for most of them, backpacking up to 14,000 feet is a big adventure. They learn new skills, they tire even their young bodies, and they confront fears and obstacles well beyond those of familiar suburban life. As a result, they come away "high" on themselves, with a sense of their own capability and, we hope, with the thought that they may be able to live their lives a little better, a little differently, than when they entered the course (Bandura, 1977; Ewert, 1983; Gass, 1987; McDonald, 1983; Kaplan and Kaplan, 1983; Schlein, Lais, McAvoy and Schatz, 1990; Young and Crandall, 1984).

Life With Others

The quality of our lives does not depend on us alone. It also depends deeply on the people we interact with, as the quality of theirs depends on us. When we take a small group – never more than 10 people – into the mountains together, we constitute a microcosm of the greater society. That small society does not contain anything like the full range of people and interactions that will appear in a person's life, but it has the great advantage of being eminently observable.

One of the principal reasons our students misunderstand the nature of ethics and its importance to their lives is that our modern society is so big and so complex. Size and complexity frequently insulate us from the consequences of our actions and from the consequences of others' actions as well. If we mess up one place, we can move to another. If we mistreat a friend or lover we can always, we think, find a new one. In the wilderness, however, one can't just move away or move on. Fences have to be mended, or everyone sees the consequences. The whole course lasts only three weeks, and the wilderness trip only eight to ten days, but it is a metaphor, or maybe a laboratory. It gives us a dimension of reality well beyond the classroom setting and a chance to illustrate those classroom lessons (McDonald, 1983; Stringer & McAvoy, 1992; Zook, 1986).

The Sublime

Theorists about aesthetics in the Romantic period expanded the traditional categories of appreciation from beauty alone to include the sublime. Briefly, beauty is pleasing. The sublime, by contrast, is awesome, overpowering and perhaps even on the edge of frightening.

We find both of these in the wild mountains where we take our students. And we enlist both in the service of our course. We want our students to feel the connection that Immanuel Kant made when he wrote that two things – the starry heavens above and the moral law within – filled him with unending wonder.

From the starry heavens above, from the ancient mountains around them, from the isolation of being miles from towns, roads and the signs of the life they've known – we want our students to feel wonder toward their lives. We want to disrupt the sleepwalking attitude toward life that the comforts and familiarity of the modern world call forth in nearly all of us. We want to disrupt it so students can call into question their normal ways of being and appreciate the possibility of living in new, more deliberate, committed and meaningful ways. They need to feel awe before the immensity of the heavens, the fathomless sweep of time in the ancient mountain stones, the indifference of the elements to whether they live or die. They need this because it is the path that leads them to feel what the Lakota people call the Great Mystery. They must walk that path to be shocked into questioning, in the heart of their hearts, whether they really know exactly who they are, what is important, what kind of life is worthwhile. The timeless rhythms of the natural world remind us of the wonder and mystery of the human situation. They call us to sincere and serious ethical reflection. This is the attitude with which the truly ethical life begins: openness, deep wonder, feeling that one might need and want to live in a radically different way.

This is not to say that we teach our students that all they have believed about ethics has been wrong. That would be ridiculous. It is not that we want them to give up all their previous beliefs and start anew. Rather, we seek an attitude of openness, a readiness to commit – or to recommit – to live consciously, deliberately and conscientiously. And this is a big part of why we seek wilderness.

Wilderness affords a timelessness and permanence that can be a model for students. They can seek, that is, for ethical certainty in a world full of distasteful uncertainty and ambiguity. At the same time, however, they must remain open and receptive to the inevitable change that constitutes a life fully lived – not without risk, painful at times – but deeply gratifying and enriching, if one is willing to engage in deep, ongoing ethical inquiry.

Beauty

In the wilderness, our students encounter not only the sublime, but the beautiful, and this quality of wild nature has a place in our course just as important as that of the sublime. When confronted with the sublime, we hope our students feel awe and eeriness, their apparent insignificance, and the presence of powers far greater than they are.

They need to be shaken out of their everyday complacency so that they can entertain the possibility of transforming their lives, giving them a new seriousness and deliberateness. But awe and disorientation, by themselves, could be stultifying instead of inspiring. One might respond with despair rather than dedication to the immensities of time and space, the indifference of the physical universe toward our lives.

Here, then, is the role for beauty in our course. By "beauty," we mean not only the sensuous beauty of the mountain vistas, the setting sun, the fragrance of the forest and the song of winds and birds. We mean all the simple pleasures, the feelings that life is good, that we associate with a well-planned trip in wild nature. We mean the grateful ease of rest much needed, the rich taste of food well earned, the peace of a world of gentle sounds and deep silence, the satisfaction of personal limits transcended, hard tasks accomplished. Not least, we mean the quiet calm of a simple, uncluttered and deeply satisfying life of the kind one lives, when skilled, in nature. With the right knowledge and the right companions, with effort and skill and a bit of luck, the sublimity of nature is not the final word on human life, but the environment within which we can and must create our own happiness.

By the end of the trip, the beauty, peace and satisfaction of life in the wild resonates within all who participate, and its message is unmistakable. Despair in the face of the sublime is not the justified response, for if we choose to live with wisdom, we can live in joy and happiness – we can live in beauty. The message is part of a Navajo song from long, long ago:

> In beauty, I walk
> To the direction of the rising sun
> In beauty, I walk
> To the direction traveling with the sun
> In beauty, I walk
> To the direction of the setting sun
> In beauty, I walk . . .
> All around me my land is beauty
> In beauty, I walk
>
> Navajo (Yebechi) chant

Conclusion

This is why we take our students to learn ethics in the wilderness. We do not seek to teach them a list of "*do*'s" and "*don't*'s" or even much at all about how to act in specific situations. We seek, instead, to inspire them to dedicate themselves to a passionate and personal search for ethical wisdom. We think we can show them a microcosm of their lives in wilderness, one small enough to be comprehensible, but rich enough to teach valuable lessons about how their own happiness and the happiness of those they care for depends on their possession or lack of ethical wisdom. We count on the sublimity of a life in nature to unsettle the students and open them to the possibility of a life-transforming experience. And we enlist the beauty of a life in nature to give them the experience of how rich a life well lived can really be.

What our course says about wilderness is not, we think, new or unexpected. It merely confirms what those who know wild places in fortunate circumstances have always said.

In wilderness, we are reminded of the essentials of the human condition. Because it is wild, we are there alone or in

small numbers. We are thus reminded of the dependence of our happiness and even survival on our own wisdom and the qualities of those around us. In the classroom, a student will often ask, in a tone that makes clear that the question is purely rhetorical, "Who's to say what's right or wrong?" In the wild, by contrast, it begins to dawn on them that they know a great deal about right and wrong, and that if they make the wrong choice, misery could follow with dismaying swiftness.

Wilderness also reminds us of how small and fragile, how temporary and tentative our lives are in the scale of nature's great sweep. In the city and the suburbs, one hardly notices the moon and stars, even with effort. In the wilderness, by contrast, you can't ignore them, and you can hardly ignore the messages of mystery and grandeur they convey. Life looses its settled nature, and we are called to see it for the great and uncanny mystery that it is. From such understandings can flow a greater depth of living.

Finally, we find great beauty in wilderness. It is, after all, our home, and it should be no surprise that we can find there the source of all art and music. We find peace and joy as well, in a life stripped down to its essentials so that each moment, each sensation, has the possibility of shining like a jewel.

"In wildness is the preservation of the world," Thoreau said. We hope the students in our course will say, "In wildness is the beginning of a new and richer life."

References

Bandura, A. (1977). Self-Efficacy: Toward a unifying theory of behavioral change. Psychological Review, 84,pp 191-215.

Ewert, A. (1983). Outdoor Adventure and Self-Concept: A Research Analysis. Center of Leisure Studies, University of Oregon, Eugene, OR.

_____ (1985). Why people climb: The relationship of participant motives and experience level to mountaineering. Journal of Leisure Research, 17(3):241-250.

Gass, M. (1987). The effects of a wilderness orienteering program on college students. Journal of Experiential Education, 10(2):30-33.

Kaplan, S. and Kaplan, J. (1983). Psychological benefits of a wilderness experience. In I. Altman and J. Wohlwill (eds.). Behavior and the Natural Environment, pp 163-204. New York: Plenum Press.

McDonald, D. (1983). The effect of participation in an outdoor experiential education program on self-concepts. Ph.D. Dissertation: Oklahoma State University.

Schlein, S., Lais, G., McAvoy, L. and C. Schatz, (1990). Outdoor recreation and integration: The effects on personal self-concept. Therapeutic Recreation Journal,2(4):62-70.

Stringer, A. and McAvoy, L. (1992). The need for something different: Spirituality and wilderness adventure. Journal of Experiential Education, 15(1):13-20.

Young, R. and Crandall, R. (1984). Wilderness use and self-actualization. Journal of Leisure Research, 16(2):149-160.

Zook, L. (1986). Outdoor adventure programs build character five ways. Parks and Recreation,21(1):54-57.

Encountering Heidi: Meeting Others as a Central Aspect of the River Experience

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Abstract—Over the past few decades, numerous studies have investigated relationships between encounters and the backcountry recreation experience. Although academics and professionals may recognize that meeting others in backcountry areas could result in positive interactions that are beneficial to the experience, research directed at the positive aspects of intergroup relations is still in its inception. This paper examines encounters using a symbolic interactionist framework, grounded in empirical data, and provides an interpretation of the inter-linkages between encounters, experiences, and identities. The findings are based on more than 10 years of participant observation studies on multi-day white water rafting trips in the western United States.

Who is Heidi? To put it succinctly, Heidi is someone we "encountered" in the Grand Canyon last summer. We don't know her last name or what she does in the "real" world. We only know that she was on a solo Grand Canyon river trip last July, ate spaghetti every other night and had a leaky valve on her small, blue cater-raft. We shared a large beach with her one night, the beach being large enough that we couldn't see where she was camped. We also invited her for dinner—salmon. A commercial trip on the other end of the beach, also out of view, also invited her for dinner, but they were having spaghetti, so Heidi chose to dine with us. We ate together and exchanged stories, and our boatman examined her cater-raft and shrugged his shoulders - not having any spare valves that would fit her tubes. I believe Heidi went to the other group for breakfast and had a similar type of encounter.

Although both the commercial group and our group could have considered the encounter with Heidi as a negative experience - an intrusion into our river/wilderness experience - we defined it more as part of that experience. In fact, we hoped to encounter her again as we floated downstream, and we asked commercial trips that were traveling faster than us if they had seen her: Yes, Heidi had dinner with them last night. No, her tubes still leaked.

On that trip, however, we did have a few "negative" encounters: meeting a large commercial group in a narrow canyon, with a somewhat unfriendly leader; passing a group of private boaters that were experiencing some inter-group conflicts and feared that everyone wanted to take THEIR camp; and having to crawl over a crowd of boats in the mouth of Havasu Creek and avoiding the growls of one boatman who was upset about people stepping on his boat with sandy feet. What made these encounters "unpleasant," however, was not based on the fact that they were encounters, but on various circumstances leading up to the encounters that led to the definition of the experiences. In fact, we had encounters at side attractions with a multitude of individuals that made the area seem "crowded," but we agreed that the overall impact of encountering all those people to our river experience was positive.

The concept of positive encounters seems to contradict the very nature of a back-country experience, such as a river trip. In general, a river trip through the Grand Canyon or many other Southwestern rivers is often viewed as one of the ultimate "wilderness experiences." The peaceful desert environment and deep canyon walls isolate river runners from any reminders of civilization. Indeed, a main motivation for many who venture on river trips is to escape from the "real world" and the routines of everyday life (Cohen and Taylor 1992). This aspect of the river trip experience has become central to the river runner identity. However, since many individuals share this desire to escape, albeit for only a few days to a few weeks, rivers have become popular. This means that different groups of river runners meet other groups of river runners - that is, they have numerous encounters. How do these encounters coincide with the river runner identity? In this paper, we provide a classical, symbolic interactionist interpretation of identity and the inter-relationship between encounters and identities. Following this, we briefly describe how encounters come to be interpreted as either positive or negative and identify the river guides' role in facilitating their passengers' interpretations. Finally, we examine how encounters are an important aspect of both the experience and identity of river runners.

Theoretical Framework

River Runner Identities

The river experience is often perceived as magical or extraordinary (Arnould and Price 1993). Part of the magic is associated with escaping from the rules and mundane routine of everyday life and finding oneself transformed by the beauty and remoteness of the river and its canyons (see, Cohen and Taylor 1992). This transformation has grave implications for ones identity as the individual learns to embrace becoming a river runner as it allows him or her the avenue for escape.

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While the river experience and emergent river identity are associated with the backcountry ("wilderness") setting, these also depend on joint action (Blumer 1969) - specifically, the interlinkages of actions among river runners. Various types of joint actions occur among groups of river runners, and include dramaturgical performances (Goffman 1967), identity work-up and displays (Birrell and Turowetz 1979), and danger constructions (Jonas 1999). All of these performances depend upon on witnessing audiences, which is essential in the identity construction process.

In general, an identity refers to a person's location in social life (Hewitt 1994). When a person has identity, "he [or she] is situated, that is, cast in the shape of a social object by the acknowledgment of his [or her] participation or membership in social relations" (Stone 1981). The term identity is often confused with the concept of role. However, a role can be defined as a perspective from which behavior is conducted. A role in itself is lifeless, an unplayed part that has no substance until the individual claims it for his or her own and breathes life into it by identifying with it (Foote 1955). While some identities are fleeting because the roles are temporary or mundane, others are more heartfelt or intense as the individual comes to perceive that identity as part of his or her "real" self. In other words, the role and self "merges" (Turner 1976). This is typically the case for river guides who often commit a lot of time and personal resources to running rivers, and view the river runner identity as part of their "core" (Hughes 1945) or "glorified" self (Adler and Adler 1991). Passengers, on the other hand, play temporary river running roles and thus tend to have less enduring river running identities. A river trip for the passenger is often a "once in a lifetime" event and, although it may have an enduring impact on the individual, river running is less central to his or her overall definition of self.

River runner identities are not formed merely once an individual departs on a river trip. Identities, in general, are negotiated at the situational level, where they are enacted through the reciprocal process of role taking and role making (Becker 1964; Blumer 1969; Stone 1981; Strauss 1969). Consequently, identities are not stable phenomena and must be continuously constructed and reconstructed in everyday life and are only recognized and confirmed during their enactment (Cicourel 1973; Douglas and Johnson 1977; Garfinkel 1967; Kotarba and Fontana 1984; Schutz 1962). Identity construction is thus a continuous process that depends on both the activities of the individual and the ratification by a witnessing audience. On the river, this process occurs during encounters, whether they be intra- or inter-group encounters. In this paper, we focus on the latter.

Encounters occur between three main types of river running groups: commercial, private and research. Most passengers have their first, and often only, river experience on a commercial trip that they take as they would choose to take any other vacation. While passengers on commercial trips engage in leisure, the guides receive a paycheck and are thus officially working. On private trips, however, both river guides and passengers engage in leisure. As a result, private trips are often associated with heavy drinking, wild partying or merely acting as "a bunch of yahoos who don't have the slightest idea what they are doing." While many or even most private trips do not fit this description, there is a general assumption among the commercial river running community that private boaters behave much like "primates," which they are occasionally called. Because of their perceived uncivilized behavior, private trips are often associated with disruption of other groups' experiences.

While private trips can be considered a total leisure experience, research trips are quite different. Neither passengers nor river guides engage in leisure as they venture on a research trip. Those on research trips are very concerned about avoiding negative perceptions of themselves during encounters to preclude accusations of acting like private boaters:

> The TL [trip leader] broached the subject of alcohol, "You need to keep a low profile. I know the atmosphere here is to have a good time, and we are one of the most lenient research groups around. You won't see any other groups with an open beer can on the boat However, please hide your cans on the boats when we pass other groups. We are a "research" team and we don't want other groups remarking to the Park service on our partying...we need to keep a positive image in the Canyon." (Research trip, Grand Canyon)

Although the different river running roles (river guide or passenger on a commercial, private, or research trip) provide the backdrop from which to interpret encounters, the meaning of the encounter (as positive or negative) and its impact on the individual's identity are negotiated at the situational level.

Methods

All three authors wrote field notes during the summer 1998 river trip when we encountered Heidi, and compared notes during the following months. It was during such discussions that we began to focus on the social dynamics of encounters. Following this, the first author went through more than 10 years of field notes taken for another study that focused on interactions between river guides and passengers on river trips in the Southwest. These notes were written in various forms and perspectives, or "voices" (Ronai 1992). Some field notes were collected in journal format (Johnson 1975) with the first author taking the role of observer (Adler and Adler 1975; Gold 1958) and watching and recording what was going on in the setting, and reporting the "objective" things that river runners said and did. In this fashion, a "thick description" (Geertz 1973) of the river running arena was obtained. Other notes were collected to capture the more subjective aspects of the river runner self and subsequently took the form of an "auto-ethnography/ biography" (Adler and Adler 1987; Ellis 1991; Hayano 1982, 1979; Jules-Rosette 1975; Krieger 1985, 1983; Ronai 1992). In this fashion, such techniques as "interpretive recall" (Hadden and others 1989) and "systematic sociological introspection" (Ellis 1991) were used to write field notes on personal experiences as both river guide and passenger. This approach to the recording of field notes becomes important as the first author recognized that she was not only observing what was going on, but was also involved in the production of the very events reported (Mitchell 1991; Richardson 1997, 1992).

While collection of the above notes did not focus on encounters, subsequent analysis of the data,using a more focused version of grounded theory methodology (Glaser and Strauss

1967), revealed that encounters were central in the river identity construction and affirmation process.

Interpretation of the Data

Situational Interpretation of Encounters

An encounter between two or more groups of river runners can be defined as either negative or positive, depending upon the nature of the interaction and the meaning that is attributed to it by the river runners involved. One generally positively viewed encounter entails some sort of "cooperation" among the groups involved, such as through the bartering of goods and services or the exchange of information. The following field notes demonstrates this form of encounter:

> A little later, a commercial snout pulls up and asks us if we mind if they had lunch there. Sure, no problem. How do we hit them up for a tow? The boatman and swamper began to prepare lunch as the passengers went up to hike Dark Canyon. They were out of beer and the boatman comes up to see if he could swap ice for some beer. Jack just happened to have an "emergency" 12 pack hidden and was willing to give it to him, not for ice, but for a tow. "I'm not suppose to, but sure." We also gave them some of our Dutch oven cake and thought that we got a good deal for the tow (Private trip, Cataract Canyon).
>
> A Hatch commercial group came by, the boatman, being a good friend of Frank's (our boatman), gave us some ice and some badly needed tonic for our gin. We showed the passengers a book full of pictures of fish, made especially to inform the public of the important work we are doing here. It seemed as if everyone was happy with the interaction. (Research trip, Grand Canyon).

Another cooperative encounter occurs at major rapids. Various groups of river runners gather at a popular "scouting" points above the rapids to view the rapids before running them and determine the safest route through (see, Jonas 1997, 1999). Often, several groups converge at the rapids at the same time, making the scouting area seem "crowded." However, river runners typically perceive the encounters as positive; as a means of exchanging advise of how to navigate the rapids, or providing support for less experienced group or more vulnerable craft. For instance, river guides operating motorized boats will often wait below major rapids to "scoop passengers and gear out of the river" belonging to non-motorized groups. Occasionally, groups will camp together above the rapids so they can run them together the following day.

> A motor rig soon lands next to us, with crew and passengers dripping wet. They must have been as miserable as they looked, drenched and wearing little rain gear. The scrawny looking boatman didn't have anything on but a pair of shorts. He quickly darted up the rocks, probably as a means to get warm, and his passengers followed him. I later found out that the group just decided to go on a river trip on the spur of the moment and weren't equipped with rain gear. The boatman ended giving all his gear to the passengers until he had none for himself. "Do you mind if we share your camp for a bit 'til we dry off and warm up?" Jack (our TL) told him that he was welcome to camp here as there was plenty of room and his passengers didn't look as if they wanted to be drenched again today. He thanked us and it seemed as if there were to be three groups sharing the one camp. I guess it was O.K. since none of us signed up for it at the registration box. There seemed to be a sigh of relief by all the groups that we were all not planning to run the rapids until morning, when we could provide each other support (Private trip, Cataract Canyon).

Although three groups shared a relative small beach in the above field note, the situation was not defined negatively. Instead, the three groups felt more secure knowing that there were others to help them run the rapids safely. Later in this paper, we examine how encounters at rapids actually enhance the experience of danger or adventure while running the rapids, which has positive implications for the participants' river running identities.

While the three groups camped on the same beach had positive encounters, perceived competition over campsites often results in negative encounters. This is especially the case on certain stretches of rivers where there are limited campsites, as depicted in the following field notes:

> There are a lot of kayakers and canoeists on this stretch of river. They can do the flat water stretch but are motored back up river once they reach Spanish Bottoms, just upstream from the first rapid, Brown Betty. There were some that we passed that didn't seem very friendly. Maybe they were intimidated by us as we were probably competing for one of the very few camps on Green, and we were rowing as fast as we could to ensure that we would get one of those few camps before they did. (Private trip, Green River).

Negative encounters can also be defined in terms of conflicting with another groups "wilderness experience," or feeling of isolation, as the following field notes suggest:

> George, Debbie, and I were having a wonderful time playing in the falls at Shinimu, until a commercial group pulls in and all these passengers come up the canyon. We decided that it was just a bit too crowded for us, so we grab our things and leave. So much for our wilderness experience. (Private trip, Grand Canyon)

> We made camp at the nice, open sandy beach at Fern Glen, but it wasn't open for long. An AZGF group and a Midge research group soon pulled up. Some faces were recognized as the so called "scientists" flocked to the beach. Kathy [our cook] complained as she sees all the people pull up, "I don't like this when all these people come. You kinda get used to your own little group." One guy from the another group had a kayak appropriately named "INVADER." (Research Trip, Grand Canyon)

However, as we will demonstrate, the same kind of encounter (in terms of the number of individuals involved, the location, time of day, etc.) can either be evaluated as positive or negative. The evaluation often relies less on the number of encounters and more on the nature of the interaction, which results in a definition of the situation as either cooperative or competitive/ conflicting. Even an initial evaluation could be revised during the course of the interaction. For instance, an encounter that may first appear as conflicting (competition over a campsite) could ultimately turn into a positive encounter. This is illustrated in the following field note:

> We ended up having to camp near the canoeist, which made neither of us very happy. Cheryl and Matt passed their camp, and these two gals just started to yell at them - for no reason! We overheard them talking to each-other, complaining how we stole THEIR camp. It was pretty rude - we were sure

> happy that we would be rid of them tomorrow. But latter that evening, Brain and this one gal from the other group got to talking, and he brought her over to join us for some drinks. Soon, more folks came over and we all had a great time. When we passed them the next day at Spanish Bottoms, they all lined the banks of the river and mooned us! We all just cheered!! (Private Trip, Cataract Canyon)

The Facilitation of Interpretations

While encounters could be defined as either positive or negative on the surface, the way in which encounters are actually experienced is more complicated. Most river guides would have little difficulty in distinguishing a good encounter from a bad encounter. They have been on the river numerous times and have constructed certain expectations and definitions of encounters. Passengers, on the other hand, because of their limited river running experience, have few expectations or predefined notions of encounters. Consequently, river guides play an important role in facilitating passengers' interpretation of encounters. The following field note demonstrates how river guides aid passengers in viewing certain types of encounters as negative:

> Then we heard the other [motor] boatmen complaining about the dorries, who thought that they were so great. For instance, they told us how those dory boatmen would not even look at the motor boats when they passed by and instructed their passengers to look at the canyon wall, or put buckets on their heads, because they thought that they were so much better than them and that motors were evil. (Commercial Trip, Grand Canyon).

The dory passengers in the above story probably viewed every encounter with motorized boats as negative. Their experience would have been different if the dory boatmen greeted the motor groups with more respect and deference. The following field notes also illustrates how negative perceptions of encounters are potentially developed, this time with research trips:

> Donna was telling me the story of one research trip where the people worked really hard, and took the hottest time of day to take a break - sleeping in the shade, and a commercial boatman points to them and tells his passengers, "See, your tax dollars hard at work." This really pissed Donna off, "that boatman really gave us a bad reputation in the eyes of those passengers. Why couldn't he have come around when we were working our butts off so the passengers could see how hard we really work?!" (Research Trip, Grand Canyon).

The guide in the above story could have led the passengers to interpret the encounters differently, perhaps by emphasizing how hard researchers worked on the river - dawn to dusk - and that they were only taking a much deserved rest. This would make encountering the research group more positive. In fact, river guides often facilitate positive interpretations of encounters with other groups, because it is in the river guide's best interest if their passengers have an overall, enjoyable river experience. Consequently, instead of ostracizing another group by pointing out some sort of major deficiency, or how the other group's presence disrupts their own river experience, river guides often treat encounters with other groups as a normal, even entertaining part of a river trip. This is evident in the following field note:

> Soon after the commercial group from Colorado leaves, another group joins us [in Slickhorn pool - a popular attraction site]. We recognize them as the sport-yak, commercial group that we have been bumping into on the river. Actually, they camped upriver from us at John's Canyon and recognized us, "Oh, are you the group that were yelling and screaming at the other camp?" Uh yes, we were. "How was your happy hour?", asked one women, and we answered that it was just fine. Then their TL and some older male passenger, directing their conversation to Lydia and I, tell us about the skinny dippers they saw, and how the TL couldn't keep the guys from taking pictures, and how this one chap busted his automatic rewind on his camera. "Oh, were you the two that were skinny dipping?.... Another group hikes in and also recognizes us, with the boatman making some snide remark on our previous activities. So, we made a reputation for ourselves on the river. What can you expect? One of the commercial guides invited us to lunch as they hiked up all the fixing,...We hesitated for a minute, but then dove right in, mingled with the passengers, and felt as part of their group....[Later, on the river,] the group that gave us lunch passed us, being amazed by the number of people and amount of gear I had in my small boat. We asked them if they had any beer since we were out, but the guide only laughed and said he couldn't believe that we ran out of beer. We later pass him, and to our surprise, he throws us three cans of Keystone, and their passengers applauded as we dove into the water to retrieve them. (Private trip, San Juan River)

While the commercial river guides teased the private river runners for their wild antics, they did not ostracize them from their passengers, but attempted to integrate them with their group by inviting them to lunch and providing beer. By throwing beer to the private group, the commercial guide provided the material for the private boaters to further enact their scripts as "wild partiers," evidenced by their diving into the river to retrieve the beer. This both confirmed the private-boater stereotype and demonstrated acceptance of such behavior through applause. In this manner, the river guides facilitated a positive interpretation of the encounter with private river runners, with the encounter becoming a part of their river "entertainment."

Encounters as Witnessing Audiences

Encounters play an important role in shaping the identity of river runners, as other groups provide audiences that are able to recognize and confirm those identities. Consequently, when boats pass other boats or occupied camps, the groups oftentimes attempt to great each other with a wave, shout or water fight. Such recognition can also be obtained from others who are not river runners, as the following field note suggests:

> As we passed the helicopter landing on river left, we watched the nice man in suit and tie pour bottles of champagne for the good people. We also watched five or six blue helicopters land nosily to deliver more people for the champagne brunch "on the river." They probably paid a lot for their "Grand Canyon Experience." We were just freezing our butts off in the rain - enduring the third day of cold drizzle. But what about these helicopters "ruining" our wilderness experience? I noticed our guide take our snout-boat directly towards the left shore, just directly below where the good people were having brunch under the Hualapai-made shelters. They point, take pictures, and wave. We wave back, toast them with

> our beers. Oddly, I didn't notice any resentment in our group—or even annoyance. For us, it seemed merely a break in the routine of running this flatwater stretch; to watch the helicopters pass by and land, one by one. And, even more so, it gave us a sense of authenticity—even superiority. We were able to compare our "Grand Canyon experience"with theirs, which demonstrated that we were having a "real" Grand Canyon experience (getting cold, wet, sandy), while those having champagne brunch were not even getting their feet wet—so to speak. We even had "proof" that we were "real" river runners as they were taking OUR pictures - as if we were natives in this Canyon setting. (Private Trip, Grand Canyon)

There have been numerous attempts to have helicopters completely banned from the Grand Canyon, both above and below the rim, because the noise disrupts the wilderness experience. The above field note suggests, however, that encounters with such "horrid" machines could become central to the identity construction process. While the encounter was not defined positively - helicopters in the Grand Canyon are still seen as unpleasant - it did provided a comparison for the river runners. They were able to prove to themselves, and others, that they are "real" or "authentic" river runners. This authenticity was reconfirmed by recognition from those on shore, as indicated by their taking pictures of the river "natives." This type of identity affirmation occurs even if the encounter is defined as negative by individuals who are generally unaware of the implications to their identities.

When an individual engages in river rafting over a period of time, the river runner identity becomes more central to his or her overall sense of self. As this occurs, affirmation of that identity by other river runners becomes more important. This includes being recognized by name by river runners from other groups, as well as being acknowledged by appearance as a "true" river runner:

> After I hiked down the side of the canyon, I decided to venture back into the mouth of Blacktail to find some dunk pools. As I was headed out of the dark canyon, an OARS commercial group was just beginning to wander inside the canyon. The passengers were your typical commercial passengers; all dressed up in their little tourist outfits, floppy hats, a mixture of white and sunburned skin, and generally out of shape. They seemed as if they couldn't even walk on the rocky ground, probably being only used to pavement. As I greeted them, I was thinking about how they looked out-of-place in the Canyon setting, as if they didn't belong. I waited for the passengers to awkwardly scamper up the rocks and around some small pools. One gal said to me as I waited for her to pass, "Oh thank you for allowing us in your back yard." She seemed to consider me, all tanned and scratched, and dressed like a "real" river runner, someone who belonged there, as compared to her and the rest of her group. (Private Trip, Grand Canyon).

Again, the above encounter could, on the surface, be defined as negative: The river runner's wilderness experience was negatively impacted by a large group entering into the narrow canyon. Instead, it provided her with a comparison of what a "real" river runner is, which, in turn, confirmed her image of herself as "authentic."

An important aspect of a river runners' identity is being an adventurer - able to face and conquer the mighty rapids. The feeling of danger, however, must first be constructed before the river runners can experience adventure. As river guides play an important role in facilitating how passengers interpret encounters, river guides also manage passengers view of the rapids as dangers (Holyfield 1997; Jonas 1997, 1999; also see Donnelly and Young 1988; Fine and Holyfield 1996; Holyfield and Fine 1997). River guides engage in a number of rituals and performances that increases the level of danger felt by the passengers, such as when scouting rapids:

> The dance of danger begins at Lava's lip. The boats are beached, and in ritualistic fashion the guides climb to the sacred vantage, a basalt boulder about 50 feet above the cataract. Once there, weight shifts from heel to heel, fingers point, heads shake, and faces fall. This is high drama, and passengers eat it up. (Bangs 1989, p. 17)

Such performances, as well as the actual running of the rapids, typically occur in front of an audience (that is, other groups of river runners). While the river guide plays an important role in constructing the danger, the audience plays an equally important role in acknowledging that the river runners endured the danger. This is evident in the remarks below made by a river runner:

> I think people would be upset if there wasn't a crowd at Lava. I really do think that it would be a big let down if you run through Lava and no one saw you. It wouldn't be as big of a thrill, people couldn't congratulate you, and you couldn't pop open a beer and bask in the limelight. (Private Trip 6/5/93)

Thus, the performance (ritualistic displays during scouting), the action (running the rapids), and the ratification by a witnessing audience (other groups watching from shore or on boats below the rapids), both creates and confirms the identity of the participants as true adventurers.

River guides are officially "in charge" on a river trip. They take novices and passengers down the river and are in charge of their care and safety. In terms of identity, however, this can become overwhelming and river guides often seek the company of other river guides to ratify their higher status as leaders and true members of the river runner community. They then share stories, as well as help prepare for upcoming rapids:

> Earlier this morning, Jack, Sam and I walked down to the lower camp to talk to the guide of the motor trip...we were kinda glad to hear that he was running support for some commercial oar group that were to be running the drops today. He said that he would be below the drops for a couple of hours today, hanging out, scooping passengers and gear out of the river. He then told us about the rapids at this water level, stressing the importance of staying right in rapid # 15, and especially to miss the "hidden hole" in #8, "I've never seen anything under 18 feet come out of that hole right side up." I thought that was encouraging, especially since all our rafts were under 18 feet. He also told us of another private trip who, according to him, "have never seen white water and look as if they don't know what they are doing." We agreed. We have seen the group pass by earlier; five people in two 16 ft cater-rafts that, from the looks of it, didn't seem rigged appropriately for white water. (Private Trip, Cataract Canyon).

For the boatmen, sharing camp gave them the opportunity to "show their stuff," tell stories, talk about strategies, rub shoulders with famous boatmen or just talk among peers (as opposed to lowly passengers). For private trips, the positive aspects of encounters with commercial boatmen include

interaction with more experienced commercial guides (who do this for a living) and doing so under the same status. They are all river guides about to face the dangers of rapids and concerned about the safety of their passengers. Encounters with other river guides thus help ratify their glorified, river runner selves.

Implications

The major point of this paper is that encounters between groups of river runners are evaluated at the situation level and based on the individuals involved, the location, and the nature of the interaction. Rather than focussing on faceless encounters with some discrete number of users, this study views encounters as negotiations between groups of river runners that is central to the river running experience. These negotiations provide audiences that help shape and ratify one's identity, and in doing so, have an enormous potential to affect one's quality of recreation experience.

Although scores of studies have addressed relationships between encounters and recreation experiences, the majority have purposely de-personalized "encounters" to focus on quantity (that is, body counts) rather than targeting the quality of recreation experiences. By addressing the question "How much use is too much?", several studies have focused on the number of encounters; such research designs are critiqued for their ability to capture variation in numbers of encounters while issues of the quality of experiences have not been given close examination. This study re-frames the encounter issue by addressing the question "What role do encounters play regarding the quality of the river running experience?" Re-framing the research question emphasizes the quality of recreation experience; the primary critique for such research designs would assess their ability to capture the breath and depth of river running experiences. Although these two encounter-based research questions are not mutually exclusive, the question directed at understanding the quality of recreation experience is important yet has not received adequate attention within the encounter-based recreation literature.

The management implications of this study provide a qualified context to understand past research that asks the question "How much use is too much?" The effects of encounters in back-country settings are complex; understanding such effects requires the inclusion of both quantitative and qualitative aspects of encounters. Such a concern is not a new idea; more than three decades ago Wagar (1964) addressed the importance of understanding both encounters and the quality of recreation experiences. The management implications of this study reinforce Wagar's viewpoint that the quality of recreation experiences are a meaningful focus for studies examining effects of encounters.

References

Adler, Patricia; Adler, Peter. 1987. Membership Roles in Field Research. Newbury Park, CA: Sage.

Arnould, Eric; Price, Linda. 1993. River Magic: Extraordinary Experience and the Extended Service Encounter. Journal of Consumer Research. 20: 24-45.

Bangs, Richard. 1989. Metamorphosis. O'Connor, C; Birmingham, J. Lazenby, eds. First Descents: In Search of Wild Rivers. Alabama: Menasha Ridge Press: 11-20.

Becker, Howard. 1964. Personal Change in Adult Live. Sociometry, 27: 40-53.

Blumer, Herbert. 1969. Symbolic Interactionism: Perspective and Method. Englewood Cliffs: Prentice-Hall.

Birrell, Susan; Turowetz, Allan. 1979. Character Work-up and Display: Collegiate Gymnastics and Professional Wrestling. Urban Life 8: 219-46.

Cicourel, Aaron. 1973. Cognitive Sociology. New York: MacMillian.

Cohen, Stanley; Taylor, Laurie. 1992. Escape Attempts: The Theory and Practice of Resistance to Everyday Life. London: Anchor Books.

Douglas, Jack; Johnson, John. 1977. Existential Sociology. New York: Cambridge University Press.

Ellis, Carolyn. 1991. Sociological Introspection and Emotional Experience. Symbolic Interaction 14: 23-50.

Fine, Gary Alan; Holyfield, Lori .1996. Secrecy, Trust, and Dangerous Leisure: Generating Group Cohesion in Voluntary Organizations. Social Psychology Quarterly 59: 22-38.

Foote, Nelson. 1951. Identification as the Basis for a Theory of Motivation, The American Sociological Review 26: 14-21.

Garfinkel, Harold. 1967. Studies in Ethnomethodology. Englewood Cliffs, NJ: Prentice-Hall.

Geertz, Clifford 1973. The Interpretation of Cultures: Selected Essays. New York: Basic Books.

Glaser, Barney; Strauss, Anselm. 1967. The Discovery of Grounded Theory: Strategies for Qualitative Research. Chicago: Aldine.

Goffman, Erving. 1963. Stigma. New York, NY: Simon & Schauter.

Goffman, Erving. 1967. Interaction Ritual. Garden City: Doubleday.

Gold, Raymond. 1958. Roles in Sociological Field Observations. Social Forces 36: 217-23.

Hadden, Stuart; Degher, Douglas; Fernandez, Richard. 1989. Sport as a Strategic Ethnographic Arena. Arena Review 13: 9-19.

Hayano, D. 1979. Auto-Ethnography: Paradigms, Problems, and Prospects. Human Organization 38: 99-104.

Hayano, D. 1982. Poker Faces. Berkeley: University of California Press.

Hewitt, John. 1994. Self and Society: A Symbolic Interactionist Social Psychology. Boston: Allyn & Bacon.

Holyfield, Lori. 1997. Generating Excitement: Experienced Emotion in Commercial Leisure. In: Erickson, Rebecca J.; Cuthbertson-Johnson, Beverly, eds. Social Perspectives on Emotion, Volume 4. Greenwich CT: JAI Press: 257-281.

Holyfield, Lori; Fine, Gary Alan. 1997. Adventure as Character Work: The Collective Taming of Fear. Symbolic Interaction. 20:343-63.

Hughes, Everett. 1945. Dilemmas and Contradictions in Status, American Journal of Sociology, 50: 353-359.

Johnson, John. 1975. Doing Field Research. New York: Free Press.

Jonas, Lilian. 1999. Making and Facing Danger: The Construction of Strong Character on the River, Symbolic Interaction 22 (3): 247-267.

Jonas, Lilian. 1997. The Making of a River Guide: The Construction of Authority in a Leisure Subculture. Ph.D. Dissertation, University of Denver.

Jules-Rosette, B. 1975. African Apostles. Ithaca, NY: Cornell University Press.

Kotarba, Joseph; Fontana, Andrea. 1984. The Existential Self in Society. Chicago: University of Chicago Press.

Krieger, Susan. 1983. The Mirror Dance: Identity in a Women's Community. Philadelphia: Temple University Press.

Krieger, Susan. 1985. Beyond Subjectivity: The Use of the Self in Social Science. Qualitative Sociology. 8: 309-24.

Ronai, Carol Rambo. 1992. The Reflexive Self Through Narrative: A Night in the Life of an Erotic Dancer/Researcher. In: Ellis, Carolyn; Flaherty, Michael, eds. Investigating. Newbury Park: Sage: 102-124

Schutz, A. 1962. Collected Papers I: The Problem of Social Reality. The Hague: Martinus Nijhoff.

Snow, David; Anderson, L. 1987. Identity Work Among the Homeless: The Verbal Construction and Avowal of Personal Identities, American Journal of Sociology, 92(6): 1336-71.

Stone, George. 1981. Appearance and the Self: A Slightly Revised Version. In: Stone, G. P.; Faberman, H. A., eds. Social Psychology Through Symbolic Interaction, New York: Wiley.
Strauss, Anselm. 1969. Mirrors and Masks: The Search for Identity. San Francisco: Sociology Press.
Turner, Ralph. 1976. The Real Self: From Institution to Impulse, American Journal of Sociology, 81 (5): 989-1016.
Wagar, J.A. (1964). The carrying capacity of wild lands for recreation. Forest Science Monograph 7, Washington, DC: Society of American Foresters.

Is There a Shared Idea of "Wilderness" Among Outdoor Recreationists? Evidence From Three Recreation Sites

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Abstract—Little empirical research has been conducted on what "wilderness" means to the general public. This paper compares the definitions of wilderness held by four groups of outdoor recreationists at three very different sites—Grand Canyon National Park, Shenandoah National Park, and Pandapas Pond, a day-use area in the Jefferson National Forest. These groups had different demographics, setting preferences and activity preferences. Although few respondents believed they knew about the legal definition of wilderness, they expressed very high agreement within and across groups about the appropriateness of features such as wildlife, virgin forest and rugged terrain. There was less consensus about shelters, developed trails and improved campsites.

The National Wilderness Preservation System (NWPS) encompasses over 100 million acres of public lands in the United States today. As the land base expands and use of these areas increases, managers are turning their energies from designation to management. How will we manage these resources in coming years? Historically, the heart of wilderness management has been the 1964 Wilderness Act, whose guiding principles were developed early in this century. This traditional wilderness idea gives special consideration to lands that are pristine or untouched (or "untrammeled"), remote or difficult to access (or "where man visits but does not remain") and large (at least 5,000 acres). It calls for provision of solitude and primitive forms of recreation. Even after the 1964 Act was "weakened" by the "Eastern Wilderness Act" (1975) and other legislation, conformity with these original principles has led to restrictions on use, regulation of camping and policies of "letting nature take her course."

Recent years have seen questions about the wisdom of letting the traditional "wilderness idea" drive management. Challenges to the wilderness idea have come from several directions (Callicott and Nelson 1998). Some argue that the premises for defining wilderness areas are factually incorrect. They argue that land seemingly "untouched" and unaffected by humans has, in fact, been heavily used and altered in the past. They question how large is "large" and point to wilderness areas as small as three acres. Others contend that by focusing attention solely on already-designated wilderness areas, often disdainfully characterized as "rock and ice" areas, we fail to protect many ecologically and biologically important areas. Still other opponents of the wilderness idea charge that it is managerially misguided; it leads to "hands off" preservation management, when active restoration might be preferable for achieving certain goals.

These types of challenges leave managers facing the conundrum of how and for whom to manage wilderness. One common assertion used to justify "traditional" wilderness management is that wilderness managed in accord with the Wilderness Act provides unique recreation opportunities and fits the American public's vision of wilderness. If so, managing for solitude, lack of development and natural processes may be justifiable.

Surprisingly few studies have explored whether the wilderness ideal actually reflects contemporary public beliefs and values. Therefore, our purpose in this study is to explore the extent to which various groups of outdoor recreationists adhere to the traditional wilderness idea. We build on preliminary research conducted at Shenandoah National Park (SNP) in 1997, which concluded that most wilderness hikers did, in fact, hold ideas very consistent with Wilderness Act prescriptions (Hall 1998). One limitation of that research was its focus on a single group of people, wilderness hikers who might be expected to know more about wilderness. Certainly, they accept wilderness management enough to visit such areas. Thus, we expanded our research to include two very different areas in 1998 and 1999. We reasoned that if most respondents felt similarly about wilderness, we would have more compelling evidence for the existence of a widely-held cultural model.

Methods

Questionnaire Development

In the fall of 1997, we conducted a series of 127 open-ended, tape-recorded interviews of SNP visitors. The focus of those interviews was to elicit information from visitors, in their own words, about what they think should belong in wilderness, and what wilderness should look like and provide. Overwhelmingly, the visitors interviewed defined the primary function of wilderness as a nature preserve; however, they also recognized that Wilderness is and should be accessible for recreation.

Content analysis of the interview data revealed high levels of agreement among these visitors for some features such as presence of wildlife (table 1). Although the individual

In: McCool, Stephen F.; Cole, David N.; Borrie, William T.; O'Loughlin, Jennifer, comps. 2000. Wilderness science in a time of change conference—Volume 3: Wilderness as a place for scientific inquiry; 1999 May 23-27; Missoula, MT. Proceedings RMRS-P-15-VOL-3. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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Table 1—Percentage of SNP informants who mentioned five indicators of wilderness.

Volunteered response[a]	Percent
Presence of wildlife	47
"Undeveloped"	32
"Natural"	28
Few encounters	20
Away from civilization	10

[a](Hall 1998).

percentages for some items (such as the word "natural" and the association of wilderness with few encounters) may appear low, they result from an unprompted, open-ended question. Survey methodologists often conclude that if more than 25 percent of respondents volunteer a given response, the majority would typically agree (Schuman and Presser 1981). Thus, we felt confident that most SNP hikers would agree about the appropriateness of these five characteristics of wilderness. However, there were other items about which respondents varied.

Based on these results, we developed several questionnaire items that could be included in quantitative research efforts. These items sought to elicit information about wilderness experience and beliefs, and familiarity with the legal definition of wilderness. In addition, we asked respondents to list the "best example" of wilderness in the U.S. Although a nationwide sampling strategy would be the best method for determining whether a shared model of wilderness exists, financial limitations rendered that impossible. Our alternative strategy entailed sampling different user groups at three disparate recreation sites. Our hope was to capture a range of visitor types. If similar results were collected from very different types of users at very different types of sites, we might conclude that there is evidence of a common model that transcends regional and social differences in recreation users. To verify that we did study different populations, our list of questions included several about sociodemographic characteristics and recreational experiences and preferences.

Study Sites

Shenandoah National Park (SNP)—Located in western Virginia, SNP is nestled in the Blue Ridge Mountains. The Park is primarily forested, although it was once extensively farmed. Due to the long, narrow shape of the Park, no area is more than 10 miles by trail from a paved road. Within the Park are 79,579 acres of formally designated wilderness. SNP is within a day's drive of several large urban centers, including Washington, D.C.; each year, 1.9 million visitors come for primarily spontaneous, inexpensive day use (USDI National Park Service 1998).

We sampled SNP visitors on randomly selected blocks of days between May and October, 1998. Researchers collected 2,402 on-site surveys from visitors at 23 trailheads and several overnight backcountry permitting stations. These surveys obtained demographic information and names and addresses. Mail questionnaires were sent to the 1,660 U.S. residents who provided their names and addresses. Of these, 825 usable responses were returned, resulting in a usable response rate of 49.7%.

Grand Canyon National Park (GCNP)—Although GCNP does not currently have any formally designated wilderness areas, the area is considered de facto wilderness; in fact, many believe it to offer the premier wilderness river trip because of the length of the Colorado River (277 miles of whitewater) and its lack of development (with the sole exception of Phantom Ranch and permitted motor use). The Park is currently the site of an ongoing, contentious debate about the desirability of formal wilderness designation. Although the entire Park receives 3.9 million annual visitors, only 27,000 of these users are boaters (mostly whitewater rafters) on the river. Only the river users—both commercially outfitted and private—were included in the data collection for this study. Whether commercial or private, a river trip down the Colorado River is expensive (commercial passengers pay approximately $150 to $300 per day) and requires a great deal of advance planning (private boaters wait as long as 10 years to receive a permit). A full-canyon trip lasts a minimum of seven days (although some people hike out after three to five days when they reach Phantom Ranch), and many are more than 10 days. Thus, the setting probably attracts different users than hike at SNP, and the experience is quite different.

Participant observers accompanied both commercial and private trips during the summer of 1998. Visitors at the end of 39 commercial (22 motor and 17 oar) and 9 private trips completed an on-site 11-page questionnaire. The final sample size for commercial boaters was 868; for private boaters, 109 (for an overall response rate of 87%).

Pandapas Pond (PAND)—Pandapas Pond is a day-use area administered by the Washington-Jefferson National Forest in southwest Virginia. Located adjacent to a four-lane highway about eight miles west of Blacksburg, the pond is extremely accessible and popular with both local residents and university students for inexpensive, spontaneous use. During the summer, approximately 30,000 people visit Pandapas Pond each month. Anglers are attracted to the pond because it is stocked with trout throughout the summer. The small pond and surrounding recreational trails attract hikers, joggers, mountain bikers and horseback riders. In addition, numerous community and university activities are hosted there throughout the year. Facilities include several picnic tables and grills, as well as a vault toilet. The area could best be classified as semi-primitive, nonmotorized according to the Recreation Opportunity Spectrum, although it is within a quarter-mile of a major highway.

On several days during spring 1999, visitors were asked to complete a brief questionnaire when they arrived at or left the site. Of the final sample of 201 visitors (68% response rate), 43% were Virginia Tech students.

Our study sites are quite different. SNP and PAND attract day users; all GCNP respondents were on overnight trips. The two Eastern sites are forested and close to roads; GCNP is a remote desert canyon. PAND primarily attracts local visitors, while SNP attracts locals as well as people from across the country. Most GCNP visitors do not live near the park. Because of these differences, and the different types of experiences offered, we expected the samples to be rather different.

Results

Sample Comparisons

To test our assumptions about the differences between our samples, we compared them on several variables, including demographics, wilderness experience, setting preferences and activity choices. There were several significant differences on sociodemographic variables (table 2). Chi-square tests indicated no difference in gender—at each site, about 60% of the visitors were male and 40% female. However, post-hoc means comparisons revealed that boaters at GCNP are a few years older than SNP visitors, who are almost eight years older than PAND visitors. Chi-square tests also identified differences in education level. Respondents selected one of six categories (less than high school; high school diploma; some college; bachelor's degree; master's degree or equivalent; and doctorate or equivalent) as their highest level of school completed. Although approximately 75% of visitors to GCNP and SNP possess at least a bachelor's degree, almost half of the respondents at PAND were currently students at Virginia Tech still working toward a bachelor's degree.

As expected, there were also large differences in the distance traveled to arrive at the recreation site. Post-hoc means comparisons revealed that each group's mean travel distance was significantly different from the others. Commercial boaters at GCNP traveled an average of 1,592 miles; many traveled internationally to participate in a trip down the Colorado River. Private boaters also traveled a long way. In contrast, PAND users traveled only 32 miles on average; most were local residents enjoying an afternoon fishing, picnicking or walking around the pond. SNP hikers' travel distances were intermediate.

The four groups of visitors also differed in their preferred type of outdoor recreation sites (table 3). Almost two-thirds of GCNP private boaters stated a preference for "roadless backcountry or wilderness." The preferences of commercial boaters, however, were split—about one-third indicated a preference for roadless backcountry, but another third preferred sites with "roads and some facilities, but no major developments." Hikers at SNP showed a similar split between preferring roadless backcountry and sites with some facilities. Areas with roads and some facilities were preferred by 41% of PAND visitors.

Table 2—Demographics of samples at three study sites.

	GC_{pvt}	GC_{com}	SNP	PAND	*p*-value
N	109	868	825	201	
Sex					0.120[1]
M (%)	67.3	57.0	60.1	62.8	
F (%)	32.7	43.0	39.9	37.2	
Average age (years)	42.6[a]	43.0[a]	37.9[b]	30.7[c]	0.000[2]
Education (mode)	BS	BS	BS	< BS	0.000[1]
At least a BS (%)	79.7	76.0	74.6	45.9	
VT students (%)				42.7	
Average distance traveled (miles)	807[a]	1592[b]	239[c]	32[d]	0.000[2]

[1]Chi-square test.
[2]ANOVA.
[abcd]Means with the same superscript were not significantly different at $\alpha = 0.05$ (Duncan's post-hoc means comparisons).

Table 3—Responses to "What type of setting do you most prefer for outdoor recreation?" (% at each site).

	GC_{pvt}	GC_{com}	SNP	PAND
Highly developed	0	7.4	2.9	8.5
Roads and facilities, no developments	11.1	35.8	35.3	41.2
Roads, no facilities	25.9	22.5	20.5	24.6
Roadless backcountry	63.0	34.2	41.4	25.6

Chi-square = 79.2, $p < 0.0005$.

Included on questionnaires at all three sites were 13 activity, feature, or experience items for which respondents were asked to indicate their level of enjoyment (on a nine-point Likert-type scale). ANOVAs followed by Duncan's post-hoc means comparisons enabled the determination of which groups were significantly different from the others (table 4). Private boaters at GCNP and SNP hikers responded similarly to six of the 13 items—on average, they didn't like developed campsites, resorts or hiking on paved trails; they did like naturalist talks, backpacking and enjoying nature. Commercial boaters and PAND visitors responded similarly (and positively) to six items—they liked "enjoying nature," being remote from cities, sleeping outdoors, vistas, the absence of people and sightseeing by car. Private and commercial boaters at GCNP were similar on only one item (automobile touring), demonstrating that a single site can attract quite different users.

Apart from their enjoyment of car camping, the private boaters' preferences generally aligned with the "traditional" idea of wilderness. Their preferences for remoteness from cities, absence of manmade features, absence of people and vast areas were higher than other groups. They also enjoy backpacking, sleeping outdoors and car camping more than the other groups. The anomaly of car camping may be explained in part by the private boaters' activity specialization—boating trips require cars and often car camping. An alternative explanation may be that this group simply enjoys all forms of camping more than the other groups.

There were also differences in how often visitors at each site visit wilderness (table 5). Over half of the private boaters said they visit wilderness two to five times per year, as did 41 percent of SNP hikers and 31 percent of PAND visitors. About one-quarter of commercial boaters at GCNP, however, said they take wilderness trips less than once every two years. No definition of "wilderness" was provided to assist respondents in answering this question. Thus, the stated frequencies may be questionable, especially when interpreted in light of their evaluations of the site they were visiting (see below).

Beliefs about Wilderness

Given the numerous differences in sociodemographics, setting and activity preference, and wilderness experience among our study groups, our next step was to determine how they differed in views about wilderness. Our questions dealt both with knowledge of the legal definition of wilderness and

Table 4—Responses to "How do you personally feel about … during your outdoor recreation?" (mean[1] at each site).

	GC_{pvt}	GC_{com}	SNP	PAND	*p*-value[2]
Campsites with water & electric hookups	-1.1[a]	-0.2[b]	-0.7[a]	1.1[c]	0.000
Hiking on easy, paved scenic trails	-0.4[a]	0.1[b]	-0.1[a]	1.3[c]	0.000
Staying at developed resorts	-0.6[a]	0.2[b]	-0.5[a]	1.3[c]	0.000
Hearing naturalist talks	1.4[a]	1.9[b]	1.4[a]	0.8[c]	0.000
Backpacking	2.9[a]	1.6[b]	2.9[a]	2.1[c]	0.000
Enjoying nature	3.8[a]	3.4[b]	3.8[a]	3.5[b]	0.000
Sleeping outdoors	3.5[a]	2.3[b]	2.9[c]	2.1[b]	0.000
Vast areas & enormous vistas	3.6[a]	2.9[b]	3.2[c]	2.6[b]	0.000
Absence of people	3.3[a]	2.4[b]	2.7[c]	2.3[b]	0.000
Automobile touring	0.6[a]	0.5[a]	0.0[b]	0.7[a]	0.000
Remoteness from cities	3.8[a]	2.9[b]	2.9[b]	2.8[b]	0.000
Absence of manmade features	3.5[a]	2.8[b]	3.0[b]	2.1[c]	0.000
Car camping	1.1[a]	-0.7[b]	-0.3[bc]	0.0[c]	0.000

[1]Means on a Likert-type scale, –4 = Strongly dislike, +4 = Strongly like.
[2]ANOVA.
[abc]Means with the same superscript are not significantly different at $\alpha = 0.05$ (Duncan post-hoc tests).

(more importantly) with visitors' personal beliefs and images of wilderness. Included in all questionnaires was the item, "How familiar are you with the legal definition of Wilderness?" It is important to note that these self-reports were uncorroborated by factual items. (A type of validity check, though, is presented below.) Nearly two-thirds (60.5%) of commercial boaters at GCNP admitted that they had no idea, they "didn't even know there was a land classification of 'Wilderness'" (table 6). Over half (51.3%) of SNP day hikers indicated that they had "heard of wilderness areas," but didn't know anything about the specific definition. Private boaters reported more knowledge about the definition of wilderness—43% of them knew "a little bit" and 35% knew "a lot" about it. Equal numbers (34%) of PAND users said they had "heard of" or "know a little" about the legal definition of wilderness.

Obviously, many respondents do not think they know what federal wilderness is. To begin to understand what they envision when they think of wilderness, we asked them to evaluate the site they were visiting (table 7). Almost half of the commercial boaters considered the Grand Canyon to be "wilderness—a place generally unaffected by the presence of people, providing outstanding opportunities for solitude and self-reliance." In contrast, 62% of the private boaters considered the area to be "semi-wilderness—the kind of place where complete solitude is not expected, but the environment appears mostly unaffected by people." Almost two-thirds (64%) of the SNP hikers considered the area to be semi-wilderness. At Pandapas Pond, 46% thought the area was semi-wilderness; another 44% considered it an "undeveloped recreation area—the kind of place where a natural setting is provided but seeing other people is part of the experience." What is perhaps most telling is that 9% of these respondents actually considered Pandapas Pond—a small, heavily used day-use area right on the highway—to be "wilderness." This percentage is nearly identical to that of SNP wilderness hikers.

What is "Wilderness"?

Best example—Perhaps the most straightforward method for determining what people think of as "wilderness" is to ask them to provide an example. Comparing the examples

Table 5—Responses to "How often do you usually take wilderness trips?" (% at each site).

	GC_{pvt}	GC_{com}	SNP	PAND
Never	0	14.7	4.0	7.1
Less than once every 2 years	7.5	28.3	8.5	13.1
Less than once a year	6.5	13.4	5.7	11.1
Once a year	10.3	18.0	18.5	9.6
2-5 times a year	52.3	19.8	41.1	31.3
6-10 times a year	11.2	3.2	12.1	9.6
More than 10 times a year	12.1	2.6	9.9	18.2

Chi-square = 370.4, $p < 0.0005$.

Table 6—Self-reported familiarity with the legal definition of wilderness (% at each site).

	GC_{pvt}	GC_{com}	SNP	PAND
No idea	4.6	30.5	10.1	17.5
Heard of it	17.6	41.3	51.3	33.9
Know a little	42.6	21.9	31.3	33.9
Know a lot	35.2	6.3	7.2	14.8

Chi-square = 253.2, $p < 0.0005$.

Table 7—Responses to "What type of setting and experience do you think this area currently provides?" (% at each site).

	GC_{pvt}	GC_{com}	SNP	PAND
Wilderness	13.9	45.3	10.7	9.1
Semi-wilderness	62.0	46.8	64.4	46.5
Undeveloped recreation site	24.1	7.9	24.9	44.4

Chi-square = 373.8, $p < 0.0005$.

cited by users at different sites can shed light on possible differences in what is considered wilderness. Each group of users was asked, "What place or area in the United States do you feel is the best example of a wilderness?" (This was asked in the context of their personal conception, so they were not constrained to listing units of the NWPS.) For this analysis, each answer was identified by state. (Thus, both "Rocky Mountain National Park" and "mountains in Colorado" were coded as "Colorado.") Responses varied greatly (table 8, fig. 1). The most common response by all groups was "Alaska," except for commercial boaters at GCNP, 30% of whom said the Grand Canyon was the best example of wilderness they could imagine. Of the two Eastern groups, nearly equal numbers of Pandapas Pond visitors listed a place in Virginia as listed Alaska. Interestingly, "Alaska" was most frequently listed without qualification—no specific place was described. Responses coded under "Virginia," however, were specific locations that the respondents probably knew from first-hand experience. These data show that, although there are some similarities, there are also differences between recreationists at different sites regarding the places that visitors imagine to be quintessential wilderness.

These responses show that people's ideas of wilderness appear to be formed both by prevailing cultural notions as well as by personal experience. Personal experience probably accounts for high percentages of southern states among respondents contacted in the south. However, the high percentages of Alaska and big western mountain ranges reflect a cultural commonality.

Table 8—"Best examples" of wilderness by region for 4 groups of recreationists (% of coded responses at each site).

	GC_{pvt}	GC_{com}	SNP	PAND
Number of coded responses	108	840	788	144
International area[1]			9.4	
Alaska	27.8	18.9	19.2	15.3
Western state	59.3	60.6	50.0	27.8
Southern state	0.1	2.3	18.7	23.6
Northeastern state	3.7	5.6	10.8	7.6

[1]Only SNP respondents were not limited to listing a place in the U.S.

For those "best examples" that were specific land management units, we also analyzed the type of land classification (table 9). In this, actual NWPS units were identified as such. Very few respondents (5% to 28%) listed a named unit, and the number of actual federal wilderness areas listed by all respondents ranged from only seven (PAND) to 33 (GCNP commercial boaters). Altogether, the 2,003 respondents listed only 55 different Wilderness areas.

One persistent tendency became clear when looking at who manages the areas listed—many respondents consider wilderness and national parks to be synonymous (table 10).

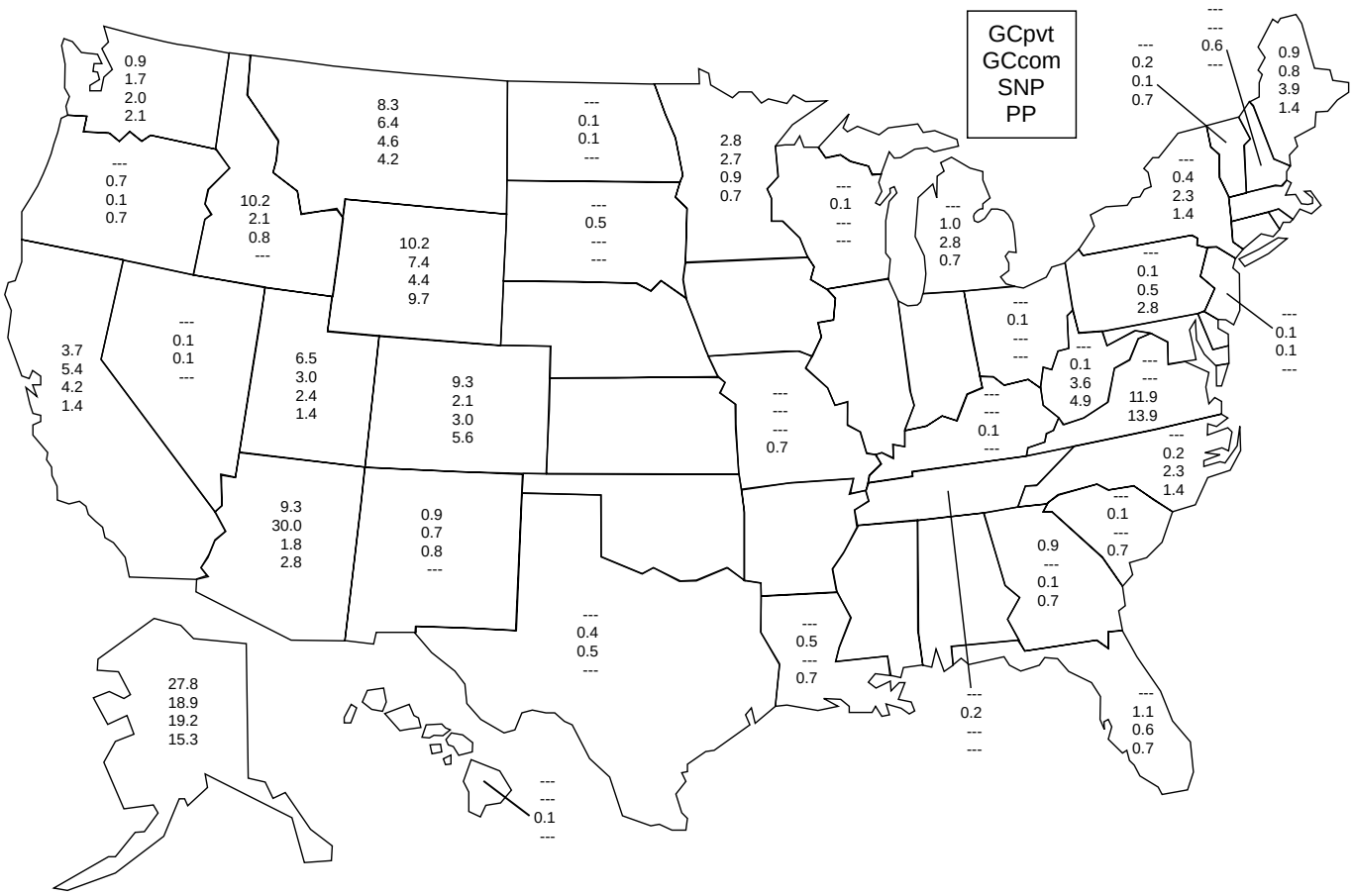

Figure 1—Responses to "What is the best example of wilderness" by state, for four groups of recreationists (% of coded responses at each site).

Many of the "best examples" (especially from commercial boaters and SNP hikers) were National Park Service units, usually the larger parks such as Glacier, Yellowstone, Rocky Mountain, and Denali. Some of these have wilderness, but many do not, and it appears most likely that respondents simply envision National Parks when asked about wilderness. Those respondents who listed actual NWPS units tended to mention areas on National Forest lands. None of the groups tended to think of Fish and Wildlife Service or Bureau of Land Management areas when asked about wilderness.

Table 9—Status of management units listed as "best example" of wilderness (% of coded responses at each site).

	GC_{pvt}	GC_{com}	SNP	PAND
Total number of coded responses[1]	108	840	788	144
NWPS units	27.8	11.9	6.7	4.9
National Park units with Wilderness[2]	6.4	8.3	17.0	2.1
Other management units	12.0	39.6	22.3	20.1
Responses not including specific units	53.8	40.2	54.0	72.9

[1]Each response was coded independently, even where a single respondent listed more than one "best example."
[2]We could not determine whether respondents were referring to the Wilderness portions of these Parks.

Table 10—Respondents' "best examples" of wilderness, organized by land management agency with managerial authority (% at each site).

	GC_{pvt}	GC_{com}	SNP	PAND
Total number of coded responses	50	503	363	39
General "National Park"[1]	0	2.0	4.4	5.2
Specific National Park	38.0	74.5	59.5	35.8
National Monument	0	0.2	1.1	0
Forest Service	53.9	20.0	17.4	41.0
Fish & Wildlife Service	4.1	0.7	1.1	2.6
Bureau of Land Management	0	0.2	0	0
Other federal land	4.0	1.6	7.4	12.9
State land	0	0.7	5.9	2.6
International land	0	0.2	3.3	0

[1]Respondent listed "National Parks" without specifying a particular unit.

Components of Wilderness—In addition to eliciting respondents' "best examples" of wilderness, each questionnaire included nine items for which respondents were asked to "indicate how much each is a part of the way you personally think about wilderness." In phrasing the question this way, we hoped respondents would answer according to the primary image that comes to mind when they think of wilderness. Several of these items (remote from cities, for example) are associated with the "traditional" idea of wilderness that this study seeks to examine. Other items (such as campgrounds with RV hookups) are definitely not traditional components of the wilderness idea. Still others (including primitive shelters for camping) fall somewhere in between and are centers of national debate over what belongs in wilderness. ANOVAs followed by Duncan post-hoc comparisons were used to explore differences among groups.

Private boaters at GCNP held the strongest opinions, and adhered most strongly to traditional ideas about what constitutes wilderness (table 11). They differed from commercial boaters on five items. Hikers at SNP were most likely to consider virgin forest an important part of wilderness. Pandapas Pond visitors considered primitive camping shelters (like those located along the Appalachian Trail) more acceptable in wilderness than did the other groups. No group felt that RV hookups were acceptable in wilderness (although each group's mean was significantly different than the others).

Generally then, the different samples varied significantly in the way they define wilderness, although they were generally consistent with the Wilderness Act and most similar on the archetypal features. The location of some of the mean scores near the end points of the scale testifies to the fairly strong and consistent images within each group. There was less agreement about other items that may or may not be consistent with the Wilderness Act (such as shelters, rugged terrain, seeing many people, and well-developed trails). Thus, respondents appear to be quite close to managers in their personal images of Wilderness, despite not knowing where federally designated wildernesses are or how they are defined.

Table 11—Components of wilderness (mean[1] at each site).

	GC_{pvt}	GC_{com}	SNP	PAND	*p*-value
Remote from cities	1.3^{a}	1.4^{ab}	1.5^{b}	1.6^{c}	0.000
Presence of wildlife	1.3^{ab}	1.3^{ab}	1.2^{a}	1.3^{b}	0.012
Virgin forest	1.7^{a}	1.8^{ab}	1.5^{c}	1.9^{b}	0.000
Rugged terrain	2.0^{a}	1.9^{ab}	1.7^{b}	2.0^{a}	0.001
Primitive shelters for camping	4.3^{a}	3.4^{b}	3.4^{b}	2.9^{c}	0.000
Seeing many other people	4.4^{a}	4.2^{b}	4.4^{a}	3.9^{c}	0.000
Well-developed, wide trails	4.5^{a}	3.9^{b}	4.0^{b}	3.4^{c}	0.000
Campsites with plank tables & cement fireplaces	4.8^{a}	4.3^{b}	4.3^{b}	3.6^{c}	0.000
Campgrounds with RV hookups	4.9^{a}	4.6^{b}	4.7^{c}	4.2^{d}	0.000

[1] Means on a Likert-type scale, 1 = A big part, 5 = Not a part at all.
[abcd] Means with the same superscript are not significantly different at $\alpha = 0.05$ (Duncan tests).

Table 12—Components of wilderness (Mean[1] for each self-reported knowledge level).

	No idea	Heard of	A little	A lot	*p*-value
Primitive shelters for camping	3.3[a]	3.4[a]	3.5[a]	3.8[b]	0.000
Campgrounds with RV hookups	4.5[a]	4.6[b]	4.7[b]	4.7[b]	0.000
Campsites with plank tables & cement fireplaces	4.2[a]	4.2[ab]	4.4[bc]	4.4[c]	0.001
Well-developed, wide trails	3.8[a]	3.9[ab]	4.0[bc]	4.1[c]	0.009
Seeing many other people	4.1[a]	4.3[b]	4.3[b]	4.2[ab]	0.024
Rugged terrain	1.9[a]	1.8[a]	1.9[a]	1.9[a]	0.081
Remote from cities	1.4[a]	1.4[a]	1.4[a]	1.4[a]	0.552
Presence of wildlife	1.3[a]	1.2[a]	1.2[a]	1.3[a]	0.650
Virgin forest	1.7[a]	1.7[a]	1.7[a]	1.7[a]	0.750

[1] Means on a Likert-type scale, 1 = A big part, 5 = Not a part at all.
[abc] Means with the same superscript are not significantly different at $\alpha = 0.05$ (Duncan post-hoc means comparisons).

Comparisons between different levels of familiarity with the legal definition of wilderness across all four groups provided interesting results about components of wilderness. Four of nine ANOVAs showed no differences by familiarity with legal definitions (table 12). Ruggedness, remoteness, wildlife and virgin forest were all considered relatively important parts of wilderness, regardless of how much the respondents claimed to know about the legal definition of wilderness. These items appear to be core components of outdoor recreation users' image of wilderness. Among the five items on which significant differences were identified are those that constitute the focus of managerial struggles.

Conclusions

We began this paper by describing some of the recent challenges to the "wilderness idea." Our data lead us to believe that many outdoor recreationists hold views more similar to that challenged notion than to the newer ideas propounded by scholars. Despite outdoor recreationists' professed ignorance of the legal definition of wilderness, our data suggest that recreationists tend to have ideas about wilderness that are consistent with the Wilderness Act and managers' interpretations of it. We feel that, even though there were statistically significant differences regarding components of wilderness (table 12), the practical significance of the differences is slight for several items that appear to form the center of a prototypic image of wilderness. Adhering to the Wilderness Act's conception, our respondents see wilderness as remote, rugged lands populated by wild animals where humans visit but do not remain. That some of these features are equally central to those who profess to know nothing about federal wilderness as those who profess to know a lot does suggests a widespread core ideal of wilderness.

This study used only three sites to triangulate upon an American model of wilderness. Obviously it would be very desirable to conduct a national study with a representative sample to investigate these questions. Although our respondents appear to represent a range of visitor types, as we had hoped, they are not representative of the U.S. public. In 1998, the average age of the U.S. population was 36.3 years, and 51% of citizens were women, while our respondents were slightly older on average and more likely to be male. Our respondents, 73% of whom possess at least a bachelor's degree, are obviously more educated than the U.S. public, of whom only 21% possess at least a bachelor's degree (U.S. Census Bureau 1998). Because education is correlated with environmental knowledge, attitudes, and wilderness use, it is possible that a representative national study would arrive at different results.

The data suggest that if we could study a broader range of sites (i.e., more developed recreation locations) we might identify more differences. The uniqueness of Pandapas Pond is particularly suggestive; among our study sites it is the most developed and could hardly be construed as wilderness with its graveled trails, developed structures, mountain bikes and highway and rifle range sounds. Visitors contacted there differed significantly from the other three samples on six of nine "features" of wilderness. Pandapas Pond is obviously only one site, but of our study sites, it is most like those familiar to most Americans. Most people do not visit wildernesses; large numbers visit developed areas. Thus, the data suggest that we should be cautious about generalizing beyond our samples to the larger public.

Future Research

This study represents a first effort at understanding how outdoor recreationists envision wilderness. In future studies, it would be informative to include broader range of potential components of wilderness (for example, swamps or deserts, "a place for recreation" or "a place for natural processes"). It might also be productive to ask respondents to select from a list those characteristics that they consider to best exemplify wilderness.

We would encourage the undertaking of a wider scale, representative study of these issues. Managers are making important decisions that require public support. Some of these decisions (for example, prescribed fire or removal of exotic plants) can drastically alter the appearance of wilderness. Others (for example, restricting use to protect endangered species) can drastically alter recreational access. Knowing how Americans visualize and value wilderness can help managers predict public opinion and design informational messages explaining relevant policies.

References

Callicott, J. Baird; Nelson, Michael P., eds. 1998. The great new wilderness debate. Athens, GA: The University of Georgia Press.

Hall, Troy. 1998. Hikers' definitions of wilderness. Paper presented at the 7th International Symposium for Society and Resource Management. May 27-31, 1998. Columbia, MO.

Schuman, H.; Presser, S. 1981. Questions and answers in attitude surveys: experiments on question form, wording, and context. New York: Academic Press.

U.S. Census Bureau. 1998. http://www.census.gov/population/www/estimates/uspop.html

USDI National Park Service. 1999. Backcountry and Wilderness Management Plan, Shenandoah National Park.

In Their Own Words: Wilderness Values of Outfitter/Guides

Julia Dawn Parker
Bill Avant

Abstract—A case study of conflict between outfitter/guides and the U.S.D.A. Forest Service was conducted in the summer of 1996. This research found variations in wilderness values among outfitter/guides operating in the Sierra Nevada region. Results from the interviews conducted in this study show divergence between two types of guides. The stock-based guides (also known as packers) had a more utilitarian view of wilderness, disregarding some ecological considerations and emphasizing the wilderness experience, as the most valuable asset to wilderness. The mountaineering guides focused on the wilderness experience as well as on preserving the wilderness resource. Both packers and mountaineering guides wanted to act on their wilderness values through volunteer work for the resource management agencies. Mountaineering guides also imparted their wilderness values to their clients through education.

Through special use permits, outfitter/guides operate within wilderness and provide services to recreational users for a fee. Although the 1964 Wilderness Act allows the operation of commercial guiding and outfitting in wilderness, the actions and values of these guides and their clients can give rise to controversy about their permitted association with the wilderness. Criticisms of outfitter/guides operating in wilderness include: 1) a lack of compatibility of commercial ventures with the wilderness ideal, 2) resource damage by stock use, 3) the lack of preparedness of outfitter/guides' clients to safely use wilderness, and 4) the potential increase of wilderness users through marketing by outfitter/guides resulting in crowding of particular wilderness areas. Outfitter/guides operate on many National Forests. They have representation through organizations such as the American Mountain Guides Association and state organizations such as the Idaho Outfitter Guides Association or California Outdoors. In the National Forest studied for this research outfitter/guides wrote approximately 10% of all wilderness permits.

Many different values are derived from wilderness. Values are the evaluation of certain beliefs (that is, if you believe something to be true, whether that truth is positive or negative). In discussing wilderness values, we can address either the value derived from wilderness (benefits) or the inherent value in wilderness.

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Benefits

A great deal of research has focused on the benefits of wilderness recreation and experience. This research has provided a long list of believed benefits of wilderness. For example, Greenway (1996) discusses escape, addressing the human/nature relationship, peacefulness, and freedom. Kaplan and Kaplan (1995) discuss self confidence, simplicity, contentment and self discovery. Driver and others (1987) report that wilderness users seek to enjoy nature, reduce tension and gain physical fitness.

Inherent Value

Less prevalent is the assessment of the values placed on wilderness itself. Ecological value focuses on the provision in wilderness of an area which lacks the influence of humans. This lack of influence by humans provides a laboratory for research that can limit the factors influencing a plant or animal species or an ecological process (Henning 1987).

The lines between the two areas—benefits derived from wilderness, and inherent values in wilderness—remain unclear at some points. If wilderness is valuable to society, then society benefits from it. The line between these types of wilderness values is somewhat indistinct in the research we conducted with outfitter/guides. Because we relied on interviews, people were free to create overlapping categories. In this paper, we will analyze wilderness values as they were described to us. We present a framework for these values that aligns with the distinction between wilderness benefits and inherent values.

Methods

Key informant interviews were conducted with mountaineering guides who focus on rock climbing and mountaineering skills and packers who use pack stock to transport clients and/or gear into the wilderness operating within wilderness in the Sierra Nevada. In addition to interviews, data sources included local publications, literature from interested parties, Forest Service files and correspondence between outfitter/guides and the Forest Service.

Semi-structured interviews of nine outfitter/guides (five packers and four mountaineering guides) operating within the wilderness in the Sierra Nevada area were conducted in the summer of 1996. These interviews focused on conflict, wilderness values and wilderness education. Interviews were based on a series of questions. New information provided by the interviewees led to the development of additional questions. This allowed the interviewer to probe new

areas and develop an understanding of the issue. The interviews ranged from 45 minutes to 3 hours, depending on the brevity of interviewees answers. Interviews were tape recorded, transcribed and coded for key words and comments on specific components of the study.

Results

Existence of Wilderness Values Among Outfitter/Guides

Interviews with outfitter/guides made the existence of wilderness values clear. These interviewees choose to devote a great deal of their time and energy to making a career in wilderness recreation. Valuing wilderness and wilderness recreation was a part of their commitment to wilderness as a vocation. There were no outfitter/guides who did not value the existence and preservation of wilderness.

Differences existed between packers and mountaineering guides. The results reveal a split in terms of their utilitarian and biocentric views of wilderness. While all guides believed recreational use of wilderness was valuable, mountaineering guides' views were tempered by the value they place on the ecological components of wilderness.

Coding and categorizing interview data revealed a number of typologies of wilderness values. In some cases, these types of values match the existing literature on wilderness values. The categories developed from our research with outfitter/guides operating within wilderness in the Sierra/ Nevada include the valuation of wilderness for 1) society, 2) the environment, 3) individual development, 4) self interest and 5) acting on wilderness values.

Society

The value of wilderness to society fell into two broad categories. First, and largest, was the value of wilderness experience. Second, outfitter/guides addressed the value of wilderness for society as a whole, including existence, spiritual good and an undeveloped place.

Value of the Wilderness

All outfitter/guides, not surprisingly, felt that wilderness recreation was positive for people, whether they came as families, individuals, friends or youth groups. Within this commonly held value of wilderness experience, differences existed between packers and mountaineering guides. They manifested themselves in the balance between ecological considerations and the social values of wilderness. For example, some mountaineering guides suggested that there was a drawback to the social value of wilderness recreation because this use also degraded the wilderness resource. One mountaineering guide expressed the dichotomy of wanting people to experience wilderness and realizing the impact of that use:

> As far as bad sides go, [outfitter/guides] are taking more people into the wilderness. And consequently, we do contribute to overcrowding. We do contribute to impact. As such, the best we hope to do is to try to mitigate that...It does have an impact and it does certainly concern me and I think about it quite often when I take people to remote areas. The same thing applies to say magazine articles on remote areas and so on. So when somebody sees those and reads them, they automatically become less remote and more known.

In balancing the social and ecological values of wilderness, packers tended to believe that the social values weighed more heavily. Packers indicated the belief that ecological concerns about recreation impacts were exaggerated. Many packers suggested that impacts of very large groups in the past as well as impacts from overgrazing pack stock, had disappeared from the wilderness in the area. They also vehemently believed that access was more important than potential impacts from stock. One packer represented this general feeling:

> 52% of the land base in California is government owned lands. There's 30 million people. Somebody's going to use something, whether it's for recreation, whether you want to say it's recreation or meditation, or an experience, give it any word you want. There's some form of use that should and can occur. [Wilderness] is not something that needs to be locked up with no use. There's no reason to destroy anything in there. It's a sociological problem of somebody's idea of how many people should be someplace. It has nothing to do with reality. These decisions [about use levels] don't have anything to do with reality. They can take you where two hundred Sierra Club people were encamped at five different camps in this area. Two hundred people were there in the camps all summer and for a year at a time. You can't tell if anything was ever there. I mean, you can also go now to where there's been cabins built and they've been destroyed and you can't tell that they were there either.

The belief that use should be promoted as much as possible also relates to the packers' belief that eventually every wilderness user needs a packer. They suggested that backpacking was for the young and childless and that packers provide a valuable service to wilderness users no longer able to backpack. One packer discussed the belief that wilderness use should be made more accessible both by issuing permits more easily and by permitting any means of transportation available:

> Wilderness permits should be as easy to obtain as possible and the reason, one of the reasons I think this is I don't think the public should be discouraged from using the wilderness. ... If [people] want to go in, they should have the right to go into the wilderness by any method of their choosing.

Another packer discussed the spectrum of people using the wilderness and the extension of wilderness use among multiple generations:

> As people get older or they have handicaps, they need the service of a horse. ... In the horse world you can take 3 or 4 generations of one family.

Both packers and mountaineering guides suggested that wilderness recreation promotes support for wilderness among the public. This support is translated into voting for candidates who support wilderness preservation and introducing children to wilderness recreation.

Non-use Values

In the broad category of non-use values of wilderness to society, outfitter/guides mentioned several items, including

a mirror for comparison to developed society, spiritual value, and existence value. One mountaineering guide shows how categories of wilderness values are intertwined by discussing ecological value, as well as the need for a place where society can see its impacts:

> I guess there's a lot of reasons why wilderness is important to me... I think that humans need a place that they can go and sort of be reminded of what life is like without all the complications that we've added to the game. So that doesn't necessarily need the mountain environment but a place where you can get away from all the trappings of what a lot of people call civilization. So, I guess that's probably the strongest one. But also secondly, where there are more or less undisturbed ecosystems. And thirdly is a place that helps people see their impacts or effects. Wilderness is kind of a laboratory because it is so fragile. And, I mean, there are a lot of things that are models for a more complicated life. I mean the life around camp is a much simpler model.

Environmental Values

The interviews indicated that both mountaineering guides and packers had strong connections to the environment. They placed a value on the environment that drew them to a line of work in the wilderness. Unsurprisingly, there were similarities in environmental wilderness values between the mountaineering guides and the packers. However, the environmental values among the mountaineering guides and the packers are differentiated by the commitment to current environmental and ecological thoughts on wilderness and the level of their holistic view of the wilderness ecosystem.

Mountaineering guides conventionally differentiated themselves from packers. Some suggested that packers do a great deal of environmental damage because of their stock use. However, mountaineering guides also note that some packers behave in an environmentally sound way. One mountain guide explains his thought on similarities among guides and packers:

> I think some of us have similar interest in terms of really wanting to see [wilderness] looked after - in terms of the resource or actual forest, as far as it not being degraded.

Changing Values

Packers frequently discussed feeling left behind in terms of environmental values. These packers felt that they were the 'real environmentalists.' Many spoke of how they had been a part of the history of wilderness preservation in the Sierra Nevada. Some packers think they are caught in an environmental pendulum: Environmental concerns swing back and forth, while they, and their business, have stayed grounded and consistent. This led to feelings of confusion about rules designed to protect the wilderness environment. One packer explained:

> You see, [Forest Service] rules are not impossible. They are probably idealistic. This year the National Forest has said " you will not go around a tree, and you will not go around a snow drift." Well, ... I do not know who brought that up, but that is something that has been done for a thousand years. When you were on a trail if there was a tree down you went around it and if there was a snowbank in the wilderness you went around it, if it was safer to go around it than to go over it. And you wonder, who came up with this wonderful idea.

Another packer discussed confusion about the ban on campfires in some wilderness in the Sierra Nevada region.

> ...and then there's uncontrolled wildfires. It's OK if there is a lightning strike that burns up side of the hill - that's good - but if you have a [camp] fire it's bad. So it's interesting who's interpreting it.

Ecological and Aesthetic Values–Neither the mountaineering guides nor the packers initiated much discussion regarding the biological aspects of the wilderness. Emphasis was placed on aesthetics, including, but not limited to, packing out trash, placement of bolts for climbing, grazing stock animals and trail degradation. Although, these impacts have biological effects, the focus was clearly on how outsiders viewed the aesthetics of outfitter/guide operations. More accessibility brings more people. This, in turn, can produce more trash, more stock use and more bolts, which become a distraction from the pristine, natural, isolated feeling that the wilderness user may seek.

While neither group of outfitter/guides concentrated on biological or ecological considerations, the mountaineering guides appeared to have a more holistic view of the environment than packers. They showed a consistent desire to take care of the natural environment in its entirety. One mountaineering guide explained how the broader issue of understanding our natural environment as a resource is the core of wilderness preservation:

> It's become very apparent to me that civilization and mankind and the post-industrial melee that we are in - that often times we make decisions relative to the resources, natural resources, that don't keep pace with our knowledge school, and I think it's possible for us to charge forward possibly and compromise someplace that has a unique and credible scenic beauty and other credible wild and natural resources and compromise it... Make it too accessible for development.

When speaking about environmental wilderness values, the packers emphasized their actions to maintain the wilderness. Usually this revolved around packing out trash:

> Many of the packers over the years have led the way in environmental concerns, cleaning up the mountains. This packstation was the first one to start a major system of packing out trash, out of the back country. [We] put up sacks with a sign, it really was beneficial to the hiker. ... There's a difference in what is destruction and what some people see as destruction.

This distinction between seeing the wilderness environment holistically and aesthetically is important. Packers did not appear to be current with the ecological theories that now direct wilderness management.

Individual Development

In addition to the value of wilderness to society as a whole, outfitter/guides felt that wilderness held values for individual development. Some of the traditional benefits of wilderness recreation (Kaplan and Kaplan 1995, Greenway 1996, Driver and others 1987) were discussed by outfitter/guides. However, they tended to focus on only a few benefits.

The value of wilderness for individual development reported by outfitter/guides can be divided into several categories: 1) self-awareness through intense experience, 2) development of youth, 3) peacefulness, and 4) escape. Mountaineering guides were more likely to discuss self-awareness through intense experience. These climbing guides probably saw a mixture of benefits from adventure or high-risk recreation with the wilderness environment. One mountaineering guide provided the following insight:

> I think climbing is the quintessential wilderness activity in the sense that what it demands on the part of the participants, I think, is the very essence of what the Wilderness Act is trying to provide for people. The idea of commitment, the idea of small groups, the idea of resourcefulness, of trying yourself, in using some sort of natural environment as kind of a monitor and — I hesitate to say — measure yourself against it. But something to kind of gauge your awareness about not only the natural environment but you're physical animal self.

Youth development was a prominent theme in the interviews with packers. The packers felt that youth participation had been curtailed by the party size limitations of both the National Park Service and the Forest Service. Not only did outfitter/guides see wilderness experience as valuable to the youth themselves, many believed that if young people did not have wilderness experiences, wilderness support would decline in the future. As one packer with several decades of experience stated:

> One thing that bothers me, we used to see a lot more church groups, YMCA groups, Scout groups, and different youth groups, but those were the main ones, the church, the Y, that do wilderness trips and take those kids. A lot of them would come right out of L.A. and I think it was a great experience for them. And years [later] you'd have people bring their families back to go into the mountains that their first Wilderness experiences were on those early church trips or whatever. I don't see that happening anymore. I just don't see the youth back there. ... It kind of makes me wonder about down the road, if there isn't the youth coming on that turn into proponents of Wilderness, what will happen?

In addition to the valuable benefits of youth development and self-awareness, mountaineering guides discussed peacefulness and escape from developed society as benefits of wilderness. One guide purposefully created peaceful and quiet times for his climbing clients. Another guide suggested that people needed a place they could escape from society and live simply.

Self Interest

Financial Interest

For some outfitter/guides, especially packers, wilderness preservation was valued because it had financial benefits. While packers suggested several times that their businesses were not particularly lucrative, they were making a profit. This profit depends on the wilderness and its condition. Therefore, packers, and sometimes mountaineering guides, suggested that maintaining wilderness was in their best interest because wilderness recreation was their livelihood. One packer stated:

> Wilderness is what the outfitters rely on and I think that's what's hard for some of the wilderness outfitters to take — is people accusing them of ruining the wilderness, the backcountry and stuff like this when their livelihood solely depends on the wilderness. One for being able to do it, but the pristineness of it. That's what keeps people coming to your areas. So you have a real vested interest in the area that you service.

A mountaineering guide put his self-interest in the wilderness within the framework of working with the Forest Service to help maintain the quality of the area:

> I think there's a general rule that the guides I work with in this area are very prepared to work with the FS to educate people and also to preserve the wilderness. It's where we make our living, so, as I said earlier, we're not going to destroy it.

Sometimes self-interest or economic interest took precedence over wilderness for outfitter/guides. This tempered their view of what was appropriate, in terms of impact from recreational users. In response to a question about whether outfitter/guides ever hurt the wilderness, one packer said:

> It depends on how you define abuse, I think. Abuse could be going up there and throwing matches around and starting a fire. I mean that would be abuse, or abuse could be knowingly running back and forth with a string of mules through a wet meadow. I mean I don't think anybody intentionally abuses the wilderness. I don't think that's going on at all. I do think that in the past there have been some packers that have done a few isolated instances. I can think of a couple where there was heavy use because of a successful business enterprise and some people might term that abuse. I wouldn't term it abuse, I would say that it's probably not preferable but I would say that in a large scope of things it tends to be minimal because a lot of what would be considered or perceived as abuse, mother nature is going to take care of it in a matter of time.

Another mountaineering guide suggested that if people wanted to be guided to an area, this constituted a need for outfitter/guides.

> I suppose this would kind of bum some people out but I think of the [need for outfitter/guides] as a free market kind of thing. I mean, I know that that bums a lot of people out, the idea of this economic element of the consideration of the wilderness. But I think it's a distinct element of sort of the concept of ecosystem management. ... I think if there are people that want to go some place bad enough and there is someone that's willing to take them there, that's for gain — obviously I think it sort of becomes an economic deal.

Self-interest and extreme economic self-interest are perhaps the most antithetical to wilderness values because money-making ventures seem incompatible with wilderness as a resource for all. However, much of this rhetoric was tempered by a concern for the wilderness area. Only one outfitter/guide truly seemed to perceive little impact from recreational use of wilderness.

Personal Interest

Another part of self-interest in wilderness is the relationship between the personalities of the outfitter/guides and their chosen career. Like many people working in natural resources, outfitter/guides are attached to the outdoors,

the wilderness and their specialized recreational pursuits. Both mountaineering guides and packers had many years of experience in their field. They came into the business of wilderness outfitting and guiding from an avocation of wilderness work. One mountaineering guide told us:

> [My work is] very rewarding and very worthwhile. It keeps me in the environment that I really like and working with great people.

This was typical of most of the interviewees. Many had come into the business of packing or guiding at a fairly young age. The length of service as guides and packers ranged from 10 years to more than 35, dating back to before the Wilderness Act was passed.

Acting on Wilderness Values

Outfitter/guides acted on their wilderness values mainly through wilderness education and volunteering time and service to the Forest Service. Regarding the wilderness education techniques and substance, a distinct split between packers and mountaineering guides was apparent. Packers tended to report that they complied with the requirements of their permit to operate in wilderness by providing the "rules" to their clients. Mountaineering guides seemed to have internalized the value of wilderness education, especially "Leave No Trace" practices. Packers and mountaineering guides both reported doing some interpretive work for their clients: showing them the flora, fauna and natural history of the area.

The difference between the packer and the mountaineering guide in style of wilderness education is apparent in the following passages in which three different packers reveal this type of motivation for wilderness education:

> It's in our best interest. Here are the basic rules. You got to do this, yeah, the fires, near the lakes, sanitation, clean up after your camp, yeah.

> You can only sort of suggest the basic rules. But to be held responsible for people for days, sounds like we're sort of trying to get out of responsibility, but it's true. ... Some people listen, some people don't.

> When they begin to correspond with us in regard to a pack trip we send them information in the mail that basically is a sheet of wilderness etiquette, ideas, ethics and things having to do with low impact camping. It's taken basically from the wilderness regulation sheet.

While packers concentrated on rules, mountaineering guides talked more about imparting wilderness values onto their clients. One mountaineering guide's statement shows the thought he puts into his wilderness ethic and how that is best conveyed to his clients:

> What I want to do with the participants is I tell them or teach them that personally I divide impacts into 2 categories, those which humans find offensive and those which really have an effect on the resource. So for example fishermen making a trail around the lake and trampling the trees eventually kills the trees and that has an effect on the resource whereas a piece of plastic candy bar wrapper found on the trail is probably not that big a deal unless a critter comes along and eats it... It's not really a better or worse thing. It's just that I think that some people, especially those who haven't spent a lot of time in wilderness don't really understand why we're going off on them about why leaving an apple core matters, or an apple seed or — how extreme do you want to get? — or why we have to pack out toilet paper. Then this could be in the sense that on one hand it's kind of a style/form thing. The best style is to not leave any trace so there are some impacts that really do have an effect ... Ones we obviously want to avoid. The others are just a matter of good style, good form. We'd just as soon not have people be able to tell we were there if possible.

Another mountaineering guide discussed his desire to teach people more than technical skills in the wilderness:

> As a guide, I certainly see my role not just as taking people up and down mountains but also engendering some sort of respect for the land. And showing people how to use it and so on. And I think in that way guides fulfill a need.

These statements on wilderness education show the most striking contrast between packers and mountaineering guides. Mountaineering guides appeared to be better aligned with wilderness management practices and theory (Hendee and others 1990). They reflected the desire to practice low-impact wilderness recreation and to pass that along to their clients through example, lecture and materials. However, both groups provided low-impact camping materials to their clients. This may mean that, in comparison with non-guided visitors, clients of outfitter/guides are receiving more information on wilderness ethics.

In addition to acting on their wilderness values through education, outfitter/guides all discussed their desire to work with the managing agencies to maintain wilderness qualities. From tracking threatened and endangered species, to trail work, to search and rescue, outfitter/guides wanted to participate in wilderness management. One mountaineering guide illustrates this point well:

> It's not even community service, it's sort of something we need to put back into the resource system. So if there's any way we can be used as a resource to improve things I'd like to see them take advantage of it. ... and now what we need for the Forest Service to say is 'alright, here's some things that you can do.'

Conclusions

It is evident from our interviews that outfitter/guides value wilderness in multiple ways. They value it for the experience it provides people, for the fact of its existence, for individual and youth development, and for its financial and vocational benefits. Their values may not exactly match those of wilderness managers or align exactly with academic wilderness philosophy, but they exist in their own form. Valuation of wilderness is sometimes seen as characteristic of the elite. This case study shows that various types of people hold wilderness values. Outfitter/guides are sometimes seen as an aberration in the Wilderness Act. But the guides in this case study showed that they did support the existence of wilderness.

However, outfitter/guides should not be treated as a homogeneous group, in terms of wilderness values. There were many gradations of values evident between the packers and mountaineering guides. Most prevalent was the theme of

packers behaving in environmentally responsible ways because it was part of the permit. In contrast, mountaineering guides seemed to internalize more of the wilderness ethics and behaved in environmentally responsible ways because they thought it was the right thing to do. Packers tended to believe that they were the "real" environmentalists or conservationists. Many were instrumental in preserving wilderness areas in the Sierra Nevada. However, the wilderness ethic or environmentally sound practices had changed around them, and they felt left behind.

One of the interviews' most promising findings is the desire of outfitter/guides in the Sierra Nevada to work with the natural resource management agencies to maintain wilderness. Outfitter/guides discussed a desire to work on trails, decrease impact, monitor wilderness conditions and work in search and rescue operations to aid Forest Service employees. Because of their underlying wilderness values and their willingness to help maintain wilderness, these permittees could be a valuable tool in wilderness management in the future.

Common wilderness values provide common ground from which agency personnel can work with outfitter/guide permittees. There may be disagreements over management techniques or exact levels of impact, but perhaps wilderness advocates should work from these common goals instead of focusing on disagreements. All of the outfitter/guides advocated preserving wilderness. They saw it as a unique place that held value for society. Outfitter/guides are a unique group and should not be overlooked in the struggle to protect wilderness in the United States.

References

Driver, B., Nash, R. & Haas, G. (1987) Wilderness benefits: state of knowledge. In R. C. Lucas (Ed.) Proceedings of the National Wilderness Research Conference. Ft. Collins, CO: USDA Forest Service Intermountain Experiment Station.

Greenway, R. (1996) Wilderness experience and ecopsychology. *International journal of wilderness*. *2*. 1: 26-30.

Hendee, J., Stankey, G. & Lucas, R. (1990) *Wilderness Management*. North American Press. Golden, CO.

Henning, D. (1987) Wilderness politics: public participation and values. *Environmental Management*. *11*. 3:283-293.

Kaplan, R. & Kaplan, S. (1995) *The Experience of Nature: a psychological perspective*. Ulrich's Bookstore. Ann Arbor, MI. In: Cole, David N.; McCool, Stephen F. 2000. Proceedings: Wilderness Science in a Time of Change. Proc. RMRS-P-000. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Social Psychological Benefits of a Wilderness Adventure Program

Todd Paxton
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Abstract—Wilderness-based outdoor adventure programs are intended to produce positive change in participants. There are a significant number of these programs, with Hattie and others (1997) reporting that in 1994 alone, there were over 40,000 students participating in Outward Bound programs. Not all of these programs occur in wilderness, but significant portions of them do. A major goal of these programs is the improvement and development of participants' self-concept and self-efficacy through wilderness-based activities. These activities provide opportunities for physical, emotional and cognitive challenges and opportunities for success. Research has demonstrated that these programs have an impact on participants' awareness of themselves and others (Hattie and others 1997). Another goal of some programs is to create and foster a wilderness/environmental awareness that enhances the participants' ability to perceive and identify with the environment and to generate concern and commitment to the continued preservation of nature and wilderness (McAvoy 1987).

There has been little research on the long-term benefits of wilderness programs. Most previous studies have focused on immediate benefits. This research project examined how a wilderness adventure program influenced the self-efficacy of participants, how participants transferred their experiences from their wilderness program to their everyday lives and if these programs have a lasting impact on the participants' attitude towards wilderness.

Self-efficacy is important for an individual's general mental health. Research has found that for individuals to function proficiently and have a sound sense of well-being, positive self-efficacy is fundamental (Gecas and Burke 1995). Many previous studies conducted on self-efficacy while participating in a wilderness adventure course have overlooked the relationship between positive self-efficacy acquired through an adventure course and the application to the participants' everyday lives.

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Self-Efficacy and Wilderness Adventure Programs

Self-efficacy refers to our beliefs about our ability to execute control over our own level of functioning and the events that affect our lives. We depend on our self-efficacy to accomplish tasks, from the mundane to the complex. As Albert Bandura (1986) states,

> ...knowledge, transformational operations, and constituent skills are necessary but insufficient for accomplished performances. People often do not behave optimally even though they know fully what to do. Self-referent thought mediates the relationship between knowledge and action.

This "self-referent thought" is efficacy. A resilient sense of efficacy is needed to sustain a continual effort, which is needed for success in any situation (Bandura 1986 1991a; Gass 1993). Efficacy involves a creative propensity in which cognitive, social and behavioral sub-skills must be organized into an integrated course of action to serve innumerable purposes (Bandura 1977 1986 1991a).

Efficacy can be derived from past failures and / or accomplishment (Bandura 1982 1986 1989; Ewert 1982; Gass 1987 1990). However, the accomplishment and / or failures of the specific activity do not have to be specific to the particular situation a person is contemplating in order for that individual's efficacy to increase (Bandura 1977 1982 1986a 1986b; Gecas 1986 1989). Self-efficacy is learned from all of our prior experience and then used by the self and incorporated into self beliefs to help achieve future tasks.

An individual's positive judgment based on their efficacy promotes active involvement in activities and contributes to the growth of competencies needed in that activity (Bandura 1977). The opposite is true for perceived self-inefficacy, which retards people from developing to their fullest by preventing corrective change. Large misjudgments of personal efficacy in either direction have consequences to the individual that prevent them from being able to function to their fullest potential (Csikszentmihalyi 1975).

Individuals' knowledge of their judgment skills and their perceived capability to influence their thought patterns and emotional reactions depend greatly on their self-efficacy (Bandura 1991a). People's thoughts and emotional reactions to their actual and perceived environments are influenced by their judgments. If one judges him/herself as inefficacious, s/he perceives potential problems and difficulties as more formidable than they really are (Beck 1976; Lazarus and Launier 1978). People with a strong sense of self-efficacy organize their attentions and efforts toward the

task and, when provoked by obstacles, muster even greater effort to overcome the stressor (Bandura 1982 1991a; Csikszentmihalyi 1975 1991). Bandura (1986) has summed up how the perception of self-efficacy makes a difference in the human experience:

> People who see themselves as efficacious set themselves challenges that enlist their interest and involvement in activities; they intensify their efforts when their performances fall short of their goals, make causal ascription for failures that support a success orientation, approach potentially threatening tasks non anxiously...

Bandura's theory has guided research on studies of outdoor/adventure education (Brody and others 1988; Priest, 1993). This theory identifies some of the determinants and consequences of self-efficacy. It can help us understand how to better help participants achieve the goals of wilderness adventure programs.

Kurt Hahn, the modern-day father of outdoor/adventure education, believed that youth would take pleasure in learning if the environment were attractive to the total person (the emotional, physical and social aspects of a person). Both intra and interpersonal lessons are the basis for experiential education—that is, the total person is involved in the learning process. Experiential and adventure education has used this philosophy as the cornerstone of their development. One essential element of this philosophy is a series of intense experiences in a natural setting that produce increasingly complex and difficult challenges for an individual to master to go on to the next challenge. This is the format of the typical wilderness adventure program. Through the process of trying to succeed at accomplishing these challenges, the individual builds a sense of selfworth and concern for those in danger (Hahn, 1970).

Studies focused on aspects of self-efficacy and outdoor programs have found that efficacy improved immediately following the adventure experience. Brody, Hatfield and Spalding (1988) found that there was a direct increase in self-efficacy specifically related to high-risk sports (Klint 1990). Similarly, Koelser (1994) found that efficacy related to outdoor leadership increased immediately following a wilderness adventure program, and this increase was maintained one year following the program.

The concept of transference is an integral part of the wilderness adventure experience, though this part of the experience takes place after the actual experience has ended. Transference is the application of what the participant learned on their wilderness program (about themselves, about others, new skills, etc.) to some new challenge after their experience (Gass 1993). Gass (1993) also states that transference is one of the "most significant issues" in the adventure education model.

Method

The sample population for this research came from Voyager Outward Bound Schools headquartered in Minneapolis, Minnesota. The participants were 68 students on standard 21-day wilderness adventure courses. Eighty-four percent of the subjects had not participated in wilderness activities for an extend period of time (over two days) prior to this trip. The program format was the same for each of the courses. However, the courses differed in the physical environment in which they took place. The instructors of the courses varied depending on the physical environment (location) and the particular expertise that was required for that course. All instructors for the Voyager Outward Bound courses have been through Voyager Outward Bound Schools' training for instructors and follow the standard course format required by the school.

A control group that consisted of 50 University of Minnesota students enrolled in a third-year Kinesiology class was used in this study. This group of students closely matched the characteristics of the experimental group in age, race, education level, gender ratio, wilderness skill levels and employment status.

This research was conducted in two phases over one year. In phase one, instruments were given to the control group and the experimental group. These instruments were administered to the experimental group on the first day of their wilderness adventure program, the last day of the program and six months after their program. The control group received their instruments while attending the University of Minnesota. The three instruments used in the first phase of this research were: the Self-Efficacy Scale (adapted for this research from Bandura 1995), the Sphere-Specific Measures of Perceived Control (Paulhus, 1983), and the Multattributional Causality Scale (Lefcourt and others 1979). In addition to the three instruments, each survey included a series of open-ended questions.

Phase two of this research consisted of semi-structured telephone interviews one year after the completion of the subjects' wilderness adventure course. Phase two interviews were conducted with 20 of the 68 subjects from phase one. This group consisted of 10 males and 10 females representing all the different courses that were involved in this study. These data were then complied and analyzed with phase one's data.

Results and Discussion

The results show a significant and enduring increase in the participants' self-efficacy from pre-test through post-test and to the six-month follow-up (table 1 and 2). There were no significant gains in the control group. Not only did the self-efficacy levels increase during the 21-day wilderness course, but also they kept increasing, even up to six months after the course. This is demonstrated in figures 1 and 2.

Table 1—Mean differences on efficacy between pre and post-test 1.

Variable	Pre mean	Std. dev.	Post 1 mean	Std. dev.	T-value
Leadership	75.93	12.93	84.90	8.74	7.772***
Work	80.97	12.05	88.05	8.63	6.563***
General	41.31	3.20	43.55	2.40	4.207**
Interpersonal	38.52	4.59	40.85	3.64	1.868#
Socio-political	37.95	3.60	39.64	2.24	2.929*

#a <.10 *a <.05 **a< .01 ***a< .001.

Table 2—Change in efficacy levels between post-test 1 and post-test 2.

Variable	Post 1 mean	Std. dev.	Post 2 mean	Std. dev.	T-value
Leadership	84.90	8.74	90.09	10.32	3.894**
Work	88.05	8.63	93.31	7.86	8.328**
General	43.55	2.40	48.43	3.50	10.181**
Interpersonal	40.85	3.64	42.59	3.84	1.896
Socio-political	39.64	2.24	42.67	4.78	3.790**

#a <.10 *a <.05 **a <.01 ***a <.001.

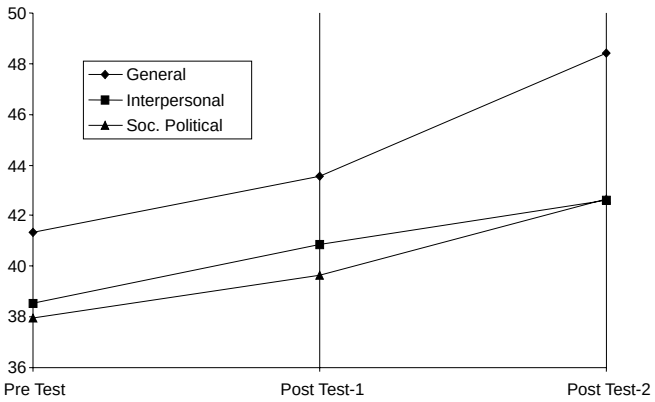

Figure 1—Graph of the pre test, post 1 test, and the post 2 test means of general, interpersonal, and social-political efficacy.

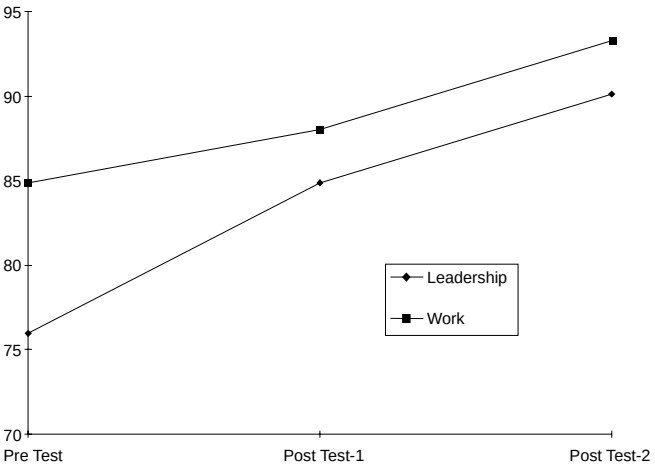

Figure 2—Graph of the pre test, post 1 test, and the post 2 test means of work and leadership efficacy.

Discussion

The interviews and the open-ended questions in the surveys indicated that the increased self-efficacy that resulted from participation in this wilderness adventure program was being transferred into the personal, social and work spheres of participants' lives. The participants who were interviewed indicated that participation in this wilderness program had resulted in increased feelings of competence, acceptance of failure as a learning opportunity and personal control.

Transference of confidence gained on the Outward Bound program to confidence in the participants' every day lives are exhibited in many of the participants' responses. A male participant on one of the canoeing courses wrote the following: "I have begun feeling more confident in my abilities as a person, stronger, that I am capable of a lot and have the power to do it." A female participant on one of the river trips reported this same sense of increased efficacy when she wrote that "I can trust my decisions and I am more motivated and determined by my own belief in myself."

Participants also demonstrated a belief in their abilities to achieve a given task, even if it meant attempting a particular goal more than once. For example, a male participant demonstrated this ability to continue through adversity in his answer to the question "Have you used any of what you learned on your Outward Bound course in your daily life:"

> I use the mentality that there is more than one way to do something and I can find a way for me to do it [that is, accomplish the task]. I don't back down if I don't achieve my goals the first or second time. I find a new way and then I see myself achieving it.

With these feelings of personal control and accepting failure as a learning experience, participants indicated a continued feeling of connection to the wilderness, even after being home for up to a year. All those interviewed stated they used the wilderness experience to help make decisions about their lives. Many of the participants spoke about how they reflect on their wilderness experience for guidance and perseverance in their life back home. A female from a canoeing course responded in the following manner when asked about what she took with her from the adventure course:

> I would say definitely it has had a major impact on all aspects of my life. . . . I've just learned to take everything one step at a time and it is so much easier to do it [succeed at challenges] that way and it makes you feel so much better. I took it [the adventure course] as a challenge. I take everything one step at a time and I look back on my trip and say I did it. I tell myself that when I face new challenges now, I did that, I can do this. I have learned to trust in myself and my abilities. I know I can do it.

The wilderness experience was also pivotal in helping the participants define themselves. For example, one female, when asked what stood out about her course, responded: "I think it was kind of a personal experience for me. I think it basically made me believe in myself a lot more. It gave me a lot more self confidence." Another participant said that

> This experience has helped me in finding myself, I now am able to better understand myself and what type of person I want to be. I feel like I know myself now in a way I never did before.

Many participants voiced this feeling of finding themselves. At the same time, participants would speak about how the "place" (the wilderness) made this possible.

All of the participants that were interviewed display feelings of stewardship of the wilderness where their experience took place. One participant said, "I feel a bond to the land, I want to always feel this so I decided that I need to take

care of that land any way I can." The wilderness was a significant component in the experience for these participants. The majority of the participants interviewed acknowledged that they have become more involved in issues regarding preservation of wild lands and want to be able to revisit these areas.

Participants indicated that they want to preserve these areas so their family and friends have the opportunity to feel and experience what they themselves have experienced in the wilderness. The majority of the participants interviewed wanted to be active in the wilderness in the future, on a much less intense level than that of an Outward Bound course. Participants spoke about wanting to use their future time in the wilderness for contemplation and reflection. One participant voiced this in the following manner

> I love the woods, but I want to enjoy the wilderness the way I enjoyed it on solo. I don't need to test myself any more, I want to walk in the solitude and enjoy the peace of the place.

Another participant stated that "I want to take time to understand what and who I am, all I want to do now is to canoe into the wilderness and just be with the wilderness." A female participant said this about how she uses the wilderness and wants to use the wilderness:

> I want to enjoy my time out [in the wilderness]. I have already tested my skills and I know that I can accomplish what I want to or need to in the wilderness. What I want to do is understanding myself and that can only come from being in the wilderness.

This study indicates that wilderness adventure courses have a lasting impact on the attitudes of participants regarding their ideas of self and their connection to wilderness. The benefits-based management models can incorporate these findings by recognizing the lasting benefits to participants of wilderness adventure programs. The basic tenants of benefits-based management is managing for desired outcomes (Driver 1999). Understanding that wilderness adventure programs produce the outcomes documented in this study will help wilderness managers decide how to manage wilderness areas. By using a benefits- based management model, policy-makers and managers can decide on how to provide opportunities that will assist in developing these benefits. Benefits-based models can incorporate these findings by acknowledging that management can draw on these participants' enduring interests in wilderness to manage and preserve wild land areas.

References

Bandura, A. 1977. Self-efficacy: Toward a unifying theory of behavioral change. Psychological Review. 84(2): 191-215.

Bandura, A. 1982. Self-efficacy mechanism in human agency. American Psychologist. 37(2): 122-147.

Bandura, A. 1986. *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall.

Bandura, A. 1984. Representing personal determinants in causal structures. Psychological Review. 91(4): p. 508-511.

Bandura, A. 1989. Regulation of cognitive processes through perceived self-efficacy. Developmental Psychology, 25(5): 729-735.

Bandura, A. (1990). Some reflections on reflections. Psychological Inquiry. 1(1): 101-105.

Bandura, A. 1991a. Social cognitive theory of self-regulation. Organizational Behavior and Human Decision Processes. 50: 248-287.

Bandura, A. 1991b. The changing icons in personality psychology. In J.H. Cantor (Ed.), Psychology at Iowa: Centennial Essays. Hillsdale, NJ: Erlbaum. 117-139.

Bandura, A. 1992. On rectifying the comparative anatomy of perceived control: Comments on "cognates of personal control". Applied & Preventive Psychology. 1: 121-126.

Bandura, A. 1995. Manual for the construction of Self-Efficacy scales. Albert Bandura, Department of Psychology, Stanford University, Stanford, CA 94305.

Bandura, A. 1997. Self-Efficacy: The exercise of control. New York: Freeman.

Bandura, A., & Cervone, D. 1986. Differential engagement of self-reactive influences in cognitive motivation. Organizational Behavior and Human Decision Processes. 38: 92-113.

Bandura, A., Jeffery, R.W., & Gajdos, E. 1975. Generalizing change through participant modeling with self-directed mastery. Behavior Research & Therapy. 13: 141-152.

Beck, A. 1976. Cognitive therapy and the emotional disorders. New York: International Universities Press.

Brody, E., Hatfield, B., & Spalding, T. 1988. Generalizations of self-efficacy to a continuum of stressors upon mastery of high risk sports skills. Journal of Sports Psychology. 10: 32-44.

Csikszentmihalyi, M. 1975. Beyond boredom and anxiety. San Francisco: Jossey-Bass.

Csikszentmihalyi, M. 1991. Flow: The psychology of optimal experience. New York: Harper Perennial.

Csikszentmihalyi, M. 1993. The evolving self. New York: Harper Perennial.

Driver, B.L. 1999. Management of Public Outdoor Recreation and Related Amenity Resources for the Benefits They Provide. In H. Ken Cordell Outdoor Recreation in American Life: A National Assessment of Demand and Supply Trends (pp.2-14). Champaign, IL: Sagamore.

Ewert, A.W. 1982. The effects of course length on the reported self-concepts of selected Outward Bound participants. (Doctoral Dissertation, University of Oregon). Dissertation Abstracts International. 43: 3111A.

Ewert, A. 1983. Adventure programming for the older adult. Journal of Physical Education, Recreation and Dance. 54(3): 64-66.

Ewert, A.W. 1989. Outdoor adventure pursuits: Foundations, models, and theories. Columbus, OH: Horizons.

Ewert, A.W. 1990. Research update: Revisiting the concept of self-esteem through outdoor experiential activities. Journal of Experiential Education. 13(2): 56.

Gass, M. 1987. The effects of a wilderness orientation program on college students. Journal of Experiential Education. 10(2): 30-33.

Gass, M. 1990. The longitudinal effects of an adventure orientation program on the retention of students. Journal of College Student Development. 31: 33-38.

Gass, M. 1993. Adventure therapy: Therapeutic applications of adventure programming. Dubuque, IA. Kendall/Hunt.

Gass, M. & McPhee, P. 1990. Emerging for recovery: A descriptive analysis of adventure therapy for substance abusers. Journal of Experiential Education. 13(2): 29-35.

Gecas, V. 1986. The motivational significance of self-concept for socialization theory. Advances in Group Processes. 3: 131-156.

Gecas, V. 1989. The social psychology of self-efficacy. Annual Review of Sociology. 15: 291-316.

Gecas, V. & Burke, P. (1995). Self and identity. In: K. Cook, G. A. Fine, & J.S. House (Eds.), Sociological Perspective on Social Psychology. Needham Heights, MA: Allyn & Bacon. 41-65.

Hahn, K. 1970. The education of thought. In Kurt Hahn and the development of Outward Bound: A compilation of essays. Outward Bound. London.

Hattie, J. 1992. Self concept. Hillsdale, NJ: Erlbaum.

Hattie, J., Marsh, H.W., Neill, J., & Richards, G. 1997. Adventure education and Outward Bound: Out-of-class experiences that make a lasting difference. Review of Educational Research. 76(1): 43-87.

Iso-Ahola, S. E., Seppo, E., LaVerde, D., & Graefe, A. R. 1989. Perceived competence as a mediator of the relationship between high risk sports participation and self-esteem. Journal of Leisure Research. 21(1): 32-39.

Klint, K. 1990. New Directions of inquiry into self-concept and adventure experiences. In: Miles, J. & Priest, S. 1990. Adventure Education. State College, PA: Venture. 163-172.

Lefcourt, H. M., VonBaeyer, C. L., Ware, E., & Cox, D. J. 1979. The multidimensional-mutiattributional causality scale: The development of a goal specific locus of control scale. Canadian Journal of Behavioral Science. 11(4): 286-304.

Lazarus, R. & Launier, R. 1978. Stress-related transactions between person and environment. In: L.A. Pervin & M. Lewis (Eds.), Perspective in Interactional Psychology New York: Plenum. 287-327.

McAvoy, L., Mitten, D., Stringer, A., Steckart, J., and Sproles, K. 1996. Group development and group dynamics in outdoor education. In McAvoy, L., Stringer, A., Bialeschki, B., and Young, A. (Eds.). Coalition for education in the outdoors third research symposium proceedings. Bradford Woods, IN. 51-62.

Paulhus, D.L. 1983. Sphere-specific measures of perceived control. Journal of Personality and Social Psychology. 44: 1253-1265.

Paulhus, D.L. 1991. Measurement and control of response bias. In Robinson, J.P., Shaver, P.R., & Wrightsman *Measures of Personality and Social Psychological Attitudes Volume 1 in Measures of social Psychological Attitudes Series*. San Diego, CA: Harcourt Brace Jovanovich. 17 – 59.

Priest, S. (1993). A new model for risk taking. The Journal of Educational Education. 16: 50-53.

Voyager Outward Bound Course Material. 1996. Minneapolis, MN: Voyager Outward Bound School.

Voyager Outward Bound Instructor Handbook. 1994. Minneapolis, MN: Voyager Outward Bound School.

How Wilderness Therapy Works: An Examination of the Wilderness Therapy Process to Treat Adolescents With Behavioral Problems and Addictions

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Abstract—This paper summarizes findings from a detailed study of the processes employed by four leading wilderness therapy programs focusing on how wilderness therapy works, the kinds of behavioral problems to which it is commonly applied, expected outcomes and the role of wilderness in the intervention and treatment process (Russell, 1999). Wilderness therapy is an emerging intervention to help adolescents overcome emotional, adjustment, addiction, and psychological problems. Thirty-eight known programs serve an estimated 12,000 clients annually, generating 350,000 visitor days of wilderness use and 143 million dollars annually.

A comprehensive definition of wilderness therapy is presented from a review of literature. An applied model of wilderness therapy is developed based on interviews with key staff who were asked to describe the theoretical basis of their program, how the process works, types of clients for whom the intervention is appropriate, and what outcomes are expected. Seven days were spent in the field with each of the four programs observing the wilderness therapy process expanding and validating these data.

A comprehensive model of wilderness therapy was then constructed from cross-case analysis of these data based on factors found in at least three of the four programs. A common theoretical basis of wilderness therapy emerged, containing an integration of wilderness programming theory and a clinically-based, eclectic, therapeutic model guided by a family systems approach. The wilderness therapy process is guided by a cleansing phase, a personal and social responsibility phase, and a transition and aftercare phase. Common anticipated outcomes included client strengthened self-concept by clients and new skills and knowledge leading to an understanding of the consequences of their behavior. These realizations typically lead clients to desire a better relationship with parents, to continue to develop emotionally, to be more appreciative and to see personal problems in a different light. The emergence of wilderness therapy demonstrates the value of wilderness as a healing source for adolescents who are not being reached by traditional therapeutic techniques.

This paper summarizes findings from a detailed study of the processes employed by four leading wilderness therapy programs focusing on how wilderness therapy works, the kinds of behavioral problems to which it is commonly applied, expected outcomes and the role of wilderness in the intervention and treatment process (Russell, 1999).

Wilderness therapy is an emerging treatment intervention in mental health practice to help adolescents overcome emotional, adjustment, addiction, and psychological problems. Wilderness therapy is often confused with the broader field of wilderness experience programs (WEP) of which it is a part. WEPs are defined as "organizations that conduct outdoor programs in wilderness or comparable lands for purposes of personal growth, therapy, rehabilitation, education or leadership-organizational development" (Friese, Hendee, & Kinziger, 1998, p. 40). Wilderness therapy features therapeutic assessment, intervention and treatment of problem behaviors, and assessment of outcomes. It involves immersion in an unfamiliar environment, group-living with peers, individual and group therapy sessions, educational curricula and application of primitive skills such as fire-making and backcountry travel. These processes are all designed to address problem behaviors by fostering personal and social responsibility and emotional growth of clients. Young people aged 12-17 are the most frequent clients.

Adolescents in the United States are more at-risk in recent years due to the influence of profound cultural change, including unstructured home environments in which both parents are working, increase in the number of single-parent families, and a media culture that bombards adolescents with images of sex, violence and excitement. These and other cultural stimuli have contributed to the epidemic of emotional disorders in US adolescents. Not enough mental health services are available that are suited for adolescents' unique needs. There is a lack of middle ground between outpatient services, which may be inadequate and to which adolescents often are unlikely to commit, and inpatient programs which may be overly restrictive (Tuma, 1989).

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Wilderness therapy is helping bridge the gap between these extremes, it's appeal strengthened by a growing reputation for economy and therapeutic efficacy when compared with other mental health services.

But despite claims of efficacy, little is known about how the wilderness therapy process works to promote changes in problem behaviors of adolescents. Mulvey, Arthur and Repucci (1993) conclude in their review of research on wilderness therapy efficacy that the "nature, extent, and conditions under which positive outcomes occur is unknown" (p. 154). Parents, juvenile authorities, and school officials looking for alternative therapeutic approaches continue to turn to wilderness therapy as a last resort for adolescents who have tried various traditional counseling approaches with little or no success. Research is needed to answer questions being addressed to the metal health profession, insurance companies, and national accreditation agencies What is involved in wilderness therapy, and how does it work? To address these questions, this study examined the wilderness therapy process focusing on what it is, how and under what conditions it works, for whom it is most effective, and the role of wilderness in the process.

Current Status of Wilderness Therapy Industry

Cooley (1998), based on his operating knowledge of the industry, estimated that approximately 10,000 adolescents were being served annually in wilderness treatment, generating 330,000 wilderness user days and 60 million dollars in annual revenue. We drew on recent surveys of the wilderness experience program industry to test and elaborate Cooley's estimates with data (Russell and Hendee, 1999).

Friese (1996) identified 500 wilderness experience programs (WEPs), defined as organizations that conduct outdoor programs in wilderness or comparable lands for purposes of personal growth, therapy, rehabilitation, education or leadership and organizational development. Thirty programs fitting the definition of expedition-based wilderness therapy were identified in this survey. Subsequently, Carpenter (1998) identified six additional wilderness therapy programs beyond these, and Crisp (1996) identified two more. Thus, a minimum of 38 wilderness therapy programs have been identified in the US. We interviewed key executives from five representative wilderness therapy programs to generate a data-based estimate of the size of the industry (Russell and Hendee, 1998). These data are presented in Table 1.

Table 1 illustrates that all five programs increased the number of clients served from 1997 to 1998, with three of the five increasing the number of trips offered. Wilderness field days (wfd) were calculated by multiplying number of clients served by the length of the wilderness trip phase of the program, generating a total of 44,775 wfd in 1997, and 51, 590 wfd in 1998 for the five programs. If we extrapolate these data as if they represented the 38 known programs, a suggested total of 11,600 clients were served in 1997 and 12,005 in 1998, generating 340,290 wfd in 1997 and 392,000 wfd in 1998 respectively. This generated annual gross revenues of $128 million dollars in 1997 and $143 million dollars in 1998.

While wilderness therapy is expensive (averaging $325 per day in the five programs surveyed), our data indicate that an average of 40 percent of clients receive financial assistance from medical insurance, and more than that in some programs. As wilderness therapy programs strive for recognition from insurance companies by receiving accreditation from national agencies such as the Council on Accreditation (COA), the trend towards co-pay assistance is likely to continue making wilderness therapy more accessible for families with limited incomes. Given reasonable support from federal land management, medical insurance, social service agencies, school and juvenile authorities, wilderness therapy should continue to expand as a viable treatment modality for adolescents with problem behaviors who may also be struggling with drug and alcohol addiction.

Despite a growing number of programs operating in the United States under the guise of "wilderness therapy," a common and accepted definition is lacking. The majority of research studies are not specific enough in describing how presenting problems are assessed by each program and how therapeutic approaches relate to target outcomes, making conclusions and findings difficult to compare. Thus we focused this investigation on the theoretical foundations of wilderness therapy in four leading wilderness therapy programs, and how their wilderness therapy process relates to outcomes, in order to better understand wilderness therapy as an intervention and treatment for adolescents with histories of problem behaviors.

Research Methods

Four leading wilderness therapy programs belonging to the Outdoor Behavior Health Care Industry Council (OBHIC) served as case studies in the exploration of theory, process, and reported outcomes associated with wilderness therapy treatment. They are: Anasazi Foundation (Anasazi) headquartered in Mesa, Arizona; Aspen Achievement Academy (Aspen) in Loa, Utah; Catherine Freer Wilderness Therapy (Freer) in Albany, Oregon; and SUWS Adolescent Programs (SUWS) in Shoshone, Idaho.

A constructivist paradigm framed the study and guided the research. The researcher spent time at four wilderness therapy programs as a participant-as-observer observing the wilderness therapy process in context. In addition, structured interviews were conducted with staff, clients, and parents. Subjectivity of the researcher was an invaluable tool in gaining confidence of research subjects, and in the qualitative tradition, was embraced. Researching the four wilderness therapy programs, or "cases," in context called for a multi-site case study design that: (1) allowed an investigation of the contemporary phenomena within its real life context; (2) the boundaries between phenomena and context are not clearly defined; and (3) allowed for multiple sources of evidence to be used (Yin, 1993).

Key staff at each program were interviewed including: (1) the program director, (2) a clinical supervisor, (3) a supervisor of admissions, and (4) an experienced lead wilderness guide or field-counselor. Each respondent was asked a series of questions related to: (1) the philosophical foundations and therapeutic benchmarks of wilderness therapy, (2) the role of wilderness in the process, (3) how wilderness therapy

Table1—Program length, number of trips, clients served, and wilderness field days, percent of clients receiving insurance co-pay, and percent aftercare placement for five wilderness therapy programs.

Program name	Program length	Wilderness treatment cost	Total staff	Number of trips		Clients served		Wilderness field days		Percent clients receive insurance assistance	Percent return home upon completion of program
				YEAR							
				97	*98*	*97*	*98*	*97*	*98*		
Anasazi	56 days	$15, 000 ($270/day)	60	27	27	187	200	10,472	11,200	60% Receive Assistance	90% Return Home 10% Aftercare Placement
Ascent	42 days	$18,500 ($440/day)	80	42	43	329	375	3,472	5,250	30% Receive Assistance	20% Return Home 80% Aftercare Placement
Aspen Achievement Academy	53 days	$15,700 ($300/day)	65	75	75	300	350	15,900	18,550	40% Receive Assistance	50% Return Home 50% Aftercare Placement
Catherine Freer	21 days	$5,850 ($280/day)	40	43	45	256	300	5,376	6,300	65% Receive Assistance	65% Return Home 35% Aftercare Placement
SUWS	21 days	$6,750 ($320/day)	58	72	75	455	490	9,555	10,290	0% Receive Assistance	40% Return Home 60% Aftercare Placement
Totals and Average	38 days (Ave.)	$12,360 ($325/day)	60 (Ave.)	259	265	1,527	1,715	44,775	51,590	40% (Ave.)	53% Return Home 47% Aftercare Placement (Ave.)

works, (4) types of clients for whom wilderness therapy works well, (5) and anticipated outcomes of the wilderness therapy process. A focus group was also conducted at each program to allow staff the opportunity to review their interview responses, hear how other staff responded, and to discuss and clarify ideas and different viewpoints.

A week was spent in the field with each program observing client case studies in the wilderness therapy treatment process and experiencing the same process in which the clients were immersed. The same pack, food, clothing, language, and rules to which students were expected to abide were adhered to by the researcher to establish rapport with the clients and leaders. Notes were taken as to the environmental setting, group dynamics and situations, client-staff interactions, environmental behaviors, and therapeutic tools and strategies used by staff to help clients address the issues which brought them to the program.

Data were stored and analyzed using the theory-building program NUD•IST (non-numerical unstructured data indexing, searching, and theorizing (Richards & Richards, 1994). This program allows for: (1) the storage and organization of document files, (2) a search for themes, (3) crossing and matching themes, (4) diagramming, (5) the creation of templates, and (6) analyzing and reporting (Creswell, 1998). Individual wilderness therapy program models were developed based on open and pattern coding techniques using an inductive approach which was performed on all data sources (Glaser, 1992; Miles & Huberman, 1994).

Results: Defining Wilderness Therapy

By synthesizing definitions in the literature and drawing upon our research, we define wilderness therapy as follows. There are two types of wilderness therapy programs: expedition and base camp (Russell, 1999; Russell and Hendee, 1999). Expedition programs remain in the field for the duration of the treatment process, while base camp programs have a structured base camp, leave on an expedition for a period of time and return to the base camp for follow-up activities. Expedition wilderness therapy programs are further organized into "contained programs" and "continuous flow" programs. Contained programs are shorter, up to three-weeks in length, in which clients and the treatment team stay together for the duration of the trip. Continuous flow programs are longer, up to eight-weeks in length, and have leaders and therapists rotating in and out of the field (eight days on and six days off is a typical rotation for field staff).

Results: A Model of Wilderness Therapy

A model of wilderness therapy was constructed based on descriptive and pattern and codes which emerged from the analysis of interview responses made by key staff at each program addressing the following aspects of wilderness therapy: (1) Theoretical Foundation; (2) Role of Wilderness, (3) Process and Practice of Wilderness Therapy; and; (4) Common Reported Outcomes. Each pattern code was reviewed for similar descriptive codes across programs which captured consistent concepts, ideas, and phenomena. For example, the pattern code *How Program Perceives Client* emerged from the analysis of a question asking staff to describe their theoretical basis of wilderness therapy. Within this pattern code, several descriptive codes were found to be similar across programs. For a descriptive code to be included in the model it had to appear in at least three of the four programs. It is important to note that this model was based on four programs included in this study. The model is not assumed to be representative of the wilderness therapy industry as a whole. The model will be used in future research to identify and validate core elements of theory, process and reported outcomes of wilderness therapy.

Theoretical Foundation of Wilderness Therapy

Figure 1 illustrates common pattern codes which comprise the theoretical foundation of wilderness therapy, which include: (A) How Program Perceives Clients, (B) Program Theoretical Foundation, and (C) How Primary Caregiver Approaches Therapeutic Relationship. Figure 1 is followed by a discussion and explanation of the descriptive and pattern codes across the four wilderness therapy programs, including common diagnoses perceived by staff as working or not working well in the wilderness therapy process.

How Program Perceives Client—Staff at each program perceive clients entering treatment as being out of control and in immediate crisis. This can be due in part to problems with drugs and alcohol, depression, violent outbursts, trouble with the law, failing grades or getting kicked out of school. Moreover, it is not only the client who is in crisis, but the entire family. This is captured in the Immediate Crisis descriptive code by Freer, "They [parents] are feeling so totally helpless, they try going to the police, try going to various centers, and they can't get anybody to help them, and they don't know what to do." Wilderness therapy staff initially work on the phone with distraught parents, trying to calm them down and determine whether wilderness therapy is what the potential client and family need.

The typical client enters wilderness therapy frightened and angry, with a deeply rooted resistance to authority. Clients deem the intervention as being a punishment, and are angry with their parents. Staff expect such resistance and embrace it, letting the process work slowly and with patience over time. Clients are also perceived as being therapeutically savvy, having been in treatment prior to wilderness therapy. Thus, the process and approach needs to be different from traditional forms of therapy in which the client has become adept at manipulation. This idea relates to the Not Manipulate descriptive category whereby staff believe that clients are not able to manipulate the process due to factors such as natural consequences. Finally, staff recognize that clients have an innate goodness, and that for some reason they have lost their way and made some bad decisions in their lives. Wilderness therapy can be seen as a chance to change their problem behaviors, helping clients find their lost sense of goodness and get their lives back on track.

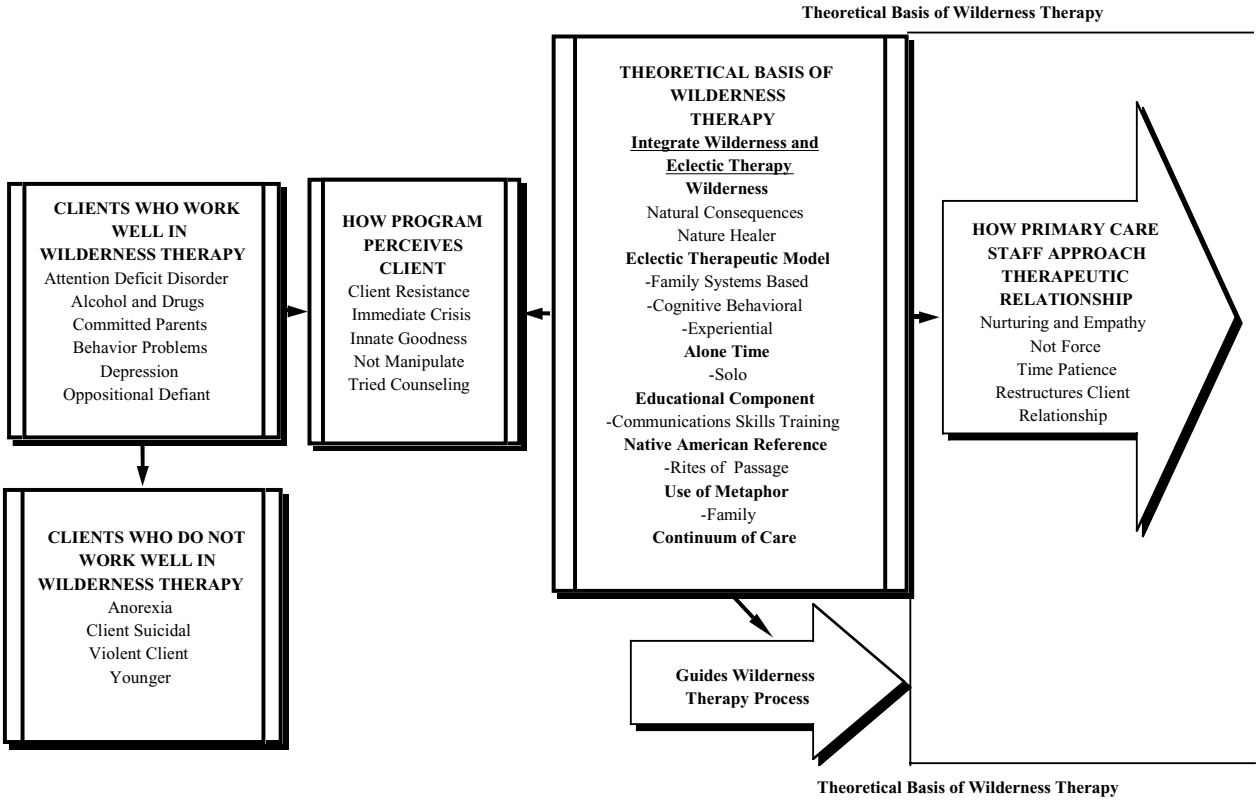

Figure 1—Theoretical foundation of wilderness therapy based on pattern codes and common descriptive codes across at least three of the four programs.

Theoretical Foundation—While each of the programs had its own unique approach to wilderness therapy, there were several common variables comprising their theoretical foundations. Many of these common concepts are based on traditional wilderness programming ideas dating back to the 1960s in programs such as Outward Bound, but which are then integrated with an eclectic therapeutic model based on a family systems perspective with a cognitive behavioral treatment emphasis. This approach integrates the therapeutic factors of a wilderness experience with a nurturing and intense therapeutic process which helps clients access feelings and emotions which have been suppressed by anger, drugs and alcohol, and depression.

Each program proposed that problem behavior of clients stems from the various environments from which they come, with the most powerful influence being the family. Because of this, the family is expected to be actively engaged in the treatment process while the client is in wilderness therapy. For example, Anasazi conducts a parent seminar that all parents are strongly encouraged to attend and the wilderness therapist works with the parents throughout the process. Aspen also conducts a seminar for parents, encourages them to be involved in counseling, and has a two-day graduation ceremony that parents attend. Freer uses family meetings at the beginning and end of the trek, and the clinical supervisor works directly with the family during the wilderness therapy process and also asks the family to commit to counseling. SUWS has a parent meeting at the end of the program to celebrate graduation and bases a major phase of the program on family dynamics, teaching clients to understand their role in the family. A variety of therapeutic models are drawn upon, including cognitive behavioral and experiential therapeutic foci. These are integrated with a family systems approach working with the entire family, the goal being restored family functioning.

Natural consequences experienced in wilderness living allow staff to step back from traditional positions of authority to which the client is accustomed. This dynamic dramatically restructures the client's relationship with the therapist and field staff and is captured in this quote by a SUWS staff member:

> In getting them out in the field and letting the wilderness environment impact them, this is what creates distress, so we don't have to do that, we don't have to apply a set of rules or expectations on them that make them uncomfortable. We don't have to get face to face with them, because the environment does that.

Interwoven in this integration of wilderness and therapy are references to Native American ceremony and ritual, including a rites of passage experience for clients. Wilderness therapy reflects rites of passage experiences practiced by cultures throughout the world, such as clients spending periods of time alone in wilderness solos to reflect on their lives and to receive insight and inspiration. Also included in the theoretical foundation were references to the use of metaphor, especially to represent the family, and an educational component with a sophisticated curricula teaching

communication skills and traditional educational and psycho-educational lessons.

How Primary Care Giver Approaches Therapeutic Relationship—The primary care staff in wilderness therapy approach the therapeutic relationship in a nurturing, caring, and empathetic way. This finding is in contrast to public perceptions of wilderness therapy based on highly publicized client deaths in Utah in the early 1990s, in which wilderness therapy was depicted as a harsh "boot camp military approach," breaking clients down through forced marathon hikes and food deprivation, so as to then build them back up and "reshape them" (Krakauer, 1995). But in the organizations studied staff approached the therapeutic relationship with compassion and patience and let clients work through their resistance and anger. They do not force change, instead allowing the environment to influence client response through natural consequences. If the client is not ready, staff step back and let other factors continue to work, such as time away from family and physical exercise, until the client is ready to consider change.

Thus, in the wilderness therapy process, the therapist-client relationship is radically different from the previous experiences that most clients have had in therapy. As a staff person from Freer stated "It's not as though there's this removed sort of person who sits in a chair an hour at a time, it's also that those people providing you guidance and giving you suggestions and giving you clear feedback are also living through the same experience with you." In wilderness treatment, the stigma associated with therapy is reduced and the leaders and therapists are seen in a different light. They are seen as role models, not alien authority figures or the enemy, further enhancing the relationship and allowing room for discussion without the stigma of traditional therapeutic roles and environments.

Wilderness Therapy Process

The wilderness therapy process is guided by phases defined as: 1) a cleansing phase, which occurs early in the program; 2) a personal and social responsibility phase, a particular emphasis once the cleansing phase is well underway or complete; and 3) a transition and aftercare phase. Figure 2 illustrates the phases of wilderness therapy as well as therapeutic tools applied during these phases and the role of the treatment team and follows with a discussion.

Cleansing Phase—The initial goal of wilderness treatment is to address client chemical dependencies by removing them from the destructive environments that perpetuated their addictions. The cleansing begins with a minimal but healthy diet, intense physical exercise, and the teaching of basic survival and self care skills. The client is also removed from intense cultural stimuli, such as dress, music, and food. The treatment team steps back and lets natural consequences teach basic lessons of wilderness living. This cleansing process prepares the client for more in-depth work later in the program.

Personal and Social Responsibility Phase—After the initial cleansing phase, natural consequences and peer interaction are strong therapeutic influences, helping clients to learn and accept personal and social responsibility. Self care and personal responsibility are facilitated by natural consequences in wilderness, not by authority figures, whom troubled adolescents are prone to resist. If it rains and they choose not to set up a tarp or put on rain gear, clients gets wet, and there is no one to blame but themselves. If they do not want to make a fire or do not learn to start fires with a bow drill or flint, they will eat raw oats instead of cooked. A goal is to help clients generalize metaphors of self care and natural consequences to real life, often a difficult task for adolescents. For example, adolescents may look at counselors and laugh when told "Stay in school and it will help you get a job." These long-term cause and effect relationships are made more cogent when therapists and wilderness guides point out the personal and interpersonal cause and effect dynamics of the clients' wilderness therapy experience to their lives back home.

There is strong evidence that social skill deficiencies are related to disruptive and antisocial behavior, which limits abilities to form close personal relationships (Mathur & Rutherford, 1994). Thus, delinquent behavior may be partly a manifestation of social skill deficits which can be changed by teaching appropriate social behaviors. Wilderness therapy takes place in very intense social units (usually six clients and three leaders) with wilderness living conditions making cooperation and communication essential for safety and comfort. Proper ways to manage anger, share emotions, and process interpersonal issues within the group are modeled and practiced in a neutral and safe environment. Thus, wilderness therapy provides hands-on learning of personal and social responsibility, with modeling and practice of appropriate social skills and cooperative behaviors, all reinforced by logical and natural consequences from wilderness conditions.

Transition and Aftercare Phase—The final weeks of the process involve clients preparing to return to the environments from which they came. Staff are working with them to process what they have learned and how to take these lessons home with them. Upon completion of the wilderness therapy program, clients must implement their newly learned self care and personal and social responsibility skills in either home or more structured aftercare placements. Preparation for this challenge is facilitated by therapists through intense one-on-one counseling and group sessions with peers. If a goal for a client was to "communicate better with parents," the therapist helps develop strategies to accomplish this goal. If abstaining from drugs and alcohol is a goal, then the therapist will work with the client to develop a behavior contract and strategy with clear expectations including weekly visits to Alcoholic Anonymous (AA) meetings, and reinforced by regular outpatient counseling sessions.

In the five programs listed in Table 1, up to 80% of the clients may go to post-wilderness therapy placement in a structured aftercare setting, such as a residential mental health facility, drug and alcohol treatment center or an emotional growth boarding school. Follow-up outpatient counseling is recommended for virtually all clients. Thus, while providing for an effective intervention, diagnosis, and initial treatment, wilderness therapy does not operate as a stand-alone cure.

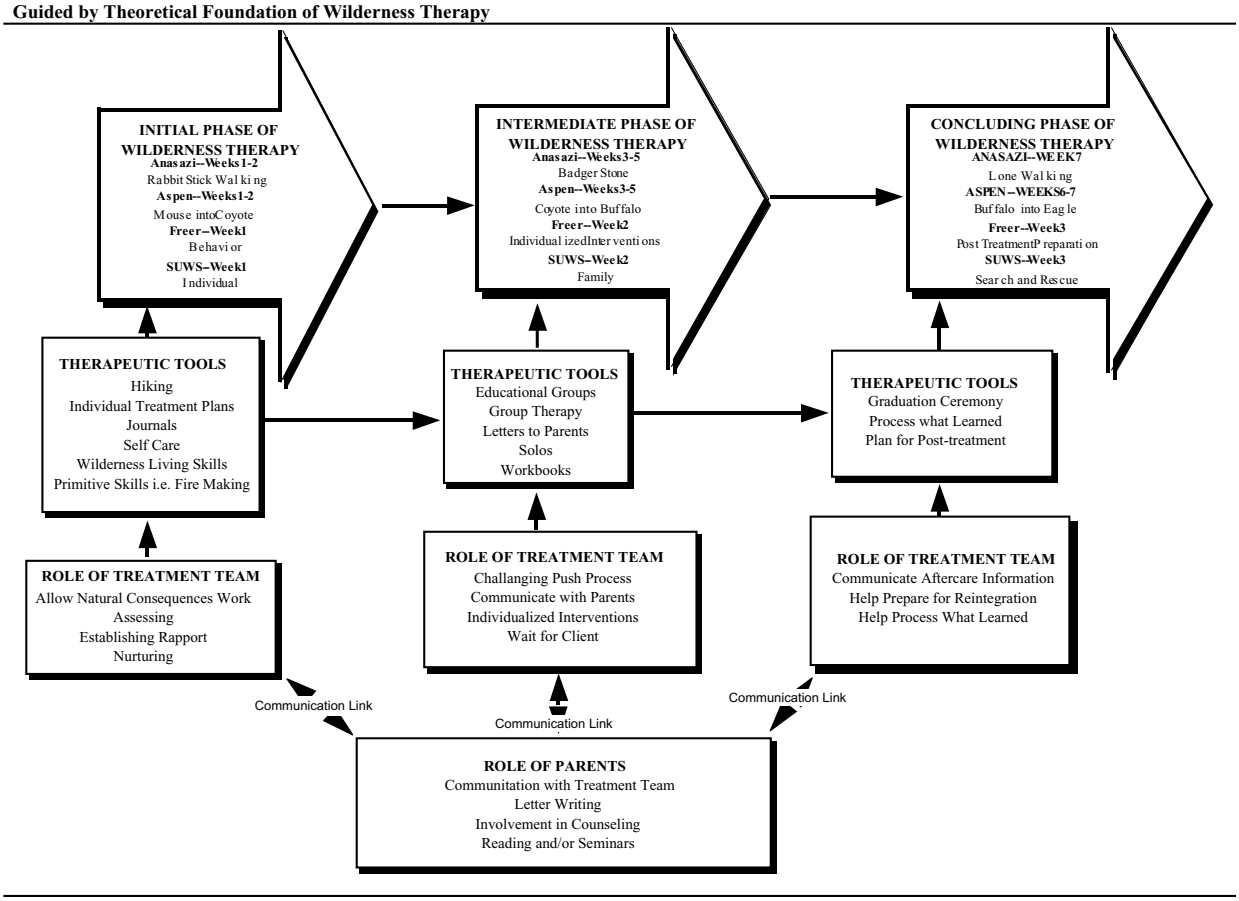

Figure 2—Pattern and descriptive codes illustrating a model of the wilderness therapy treatment process.

The Role of Wilderness in Wilderness Therapy

Therapeutic factors of wilderness at work are presented to clarify the role of wilderness in wilderness therapy. The wilderness environment, characterized by naturalness and solitude, can be seen as a therapeutic environment in and of itself. Staff were asked to explore how the wilderness experience alone was therapeutic. The question was asked: "What role does wilderness play in supporting the theoretical foundation of wilderness therapy as practiced by [program name]?" The question asked why wilderness?, or, in other words, could wilderness therapy be done in natural areas which are not wilderness, such as a state park or cabin retreat? The therapeutic factors of wilderness appeared in common descriptive codes across all programs in their description of how wilderness conditions of naturalness and solitude supported their theoretical foundation of wilderness therapy (Figure 3).

Descriptive codes of wilderness conditions in wilderness therapy act on the client to different degrees as the wilderness therapy process unfolds and we describe them as representing the three phases described earlier: "cleansing," "personal and social responsibility," and "transition and aftercare." These three phases help account for differences in program length (Freer and SUWS three weeks, and Anasazi and Aspen eight weeks)—each phase is present in each program and is merely extended in length for the longer programs.

Cleansing Phase (Cleansing-Humbling)—In the initial cleansing phase of wilderness therapy, the codes Out of Familiar Culture, Vulnerable Humbling, and Vast Open are reasoned to effect the client intensely. Because many clients come to wilderness therapy unwillingly, they have not been prepared for the experience. They are suddenly dropped in remote backcountry with very few possessions. Their wilderness living skills are limited, creating an acute feeling of vulnerability, compounded by the daunting realization that the usual comforts of home are nowhere to be found. Being removed from their immediate culture, dropped off in a desolate remote wilderness area, and being asked to hike and live in the desert for an unspecified period of time is a powerful experience for an adolescent. Because of this, these wilderness therapeutic factors are reasoned to be more powerful in the initial stages of wilderness therapy.

Personal and Social Responsibility Phase—In this phase of wilderness therapy, descriptive codes reasoned to be working intensely on the client are Appreciation and Reduces Distractions. In the initial phases clients feel a sense of appreciation for the things they do not have in wilderness, such as water and food, but have not yet moved

Figure 3—Coded responses to the question: What wilderness conditions support the theoretical foundation of wilderness therapy?

Therapeutic factors of wilderness

Descriptive code	Definition	Examples of coded response
Appreciation	Client learns a sense of appreciation as a wilderness condition which supports the theoretical foundation of wilderness therapy	So the wilderness does a lot of things. I think first off, right up front, is that it teaches an appreciation from where things come from and what you have to give up to get what we get. There's an old saying that says, one half of knowing what you want in life is knowing what you must give up to get it. In the wilderness, the wilderness just does that. (Aspen)
Cleansing Health	Wilderness cleanses the client and is a healthy environment as a wilderness condition which supports the theoretical foundation of wilderness therapy	It just seems to be a healthier environment, just sort of by design, and the more I sort of read and hear about, oh sanitariums that treat people tuberculosis, even hospitals that set up tents in New York City, just putting the tents made a difference. That has something to do with it. (Aspen)
Out of Familiar Culture	Absence of familiar culture in wilderness supports the theoretical foundation of wilderness therapy program	So the things that seem so important in their life, what they look like, who their friends are, all those kind of normal developmental things for adolescents, suddenly they're thrust into a situation where those are completely unimportant. (Freer)
Reduces Distractions	Wilderness conditions reduce distractions which supports the theoretical foundation of wilderness therapy	There's also the advantages I think of, in a lot of the treatment centers there's still distractions, and in the wilderness, that gets cut down. (Freer)
Simple Primitive Lifestyle	Wilderness conditions facilitate living more simply reflecting a primitive lifestyle which supports the theoretical foundation of wilderness therapy	I mentioned a little bit about the primitive lifestyle they lead while they are out there. I don't know if I can say a whole lot about this, but there is something more therapeutic about living in a primitive way, and it really twists your perspective on things. You're connected with how things used to be done. And it's not something that can be quantified, you can discuss it at length, but unless you have experienced it, have lived that way, it's very hard for you to grasp it. (Anasazi)
Vast Open	Wilderness conditions are vast and open which supports the theoretical foundation of wilderness therapy	And to me that's what makes it powerful because there isn't nothing out here but you. You got to face you. It's an area that grows on you slowly. If you go further west they get bigger but we're not talking huge and there's nothing but sagebrush country. There's only one place that I know that even has cactus, a small area of prickly pears. But in general there ain't a whole, and all you have is you out there. (SUWS)
Vulnerable Humbling	Wilderness conditions create a sense of vulnerability which is humbling which supports the theoretical foundation of wilderness therapy	And so I think it is very empowering for their self-esteem and yet humbling at the same time, that you know, when you're walking between these towering cliffs, you realize that you're not the center of the universe anymore. Obviously a lot of the kids, especially at this developmental stage, are very egocentric and I think this gives them a powerful dose of reality that they're not the center of the universe. (Aspen)

beyond this thinking. In the intermediate phase clients begin to feel a greater sense of appreciation for friends and family, not just cultural items. Likewise, the cultural scarcity of wilderness living offers fewer distractions allowing clients the opportunity to reflect on their lives, how they are feeling, and what is really important to them. These two factors (Appreciation and Reduces Distractions) strengthen as time goes on, and are manifested intensely in the intermediate and concluding phases of wilderness therapy.

Transition and Aftercare Phase—The common descriptive codes Cleansing Health and Simple Primitive Lifestyle are reasoned to peak in the concluding phase of wilderness therapy reflecting a cumulative process. The client is eating healthier foods, has not been doing drugs and or alcohol, and has been exercising regularly. Combined with the clean air and fresh water, wilderness is working to cleanse clients physically, helping them continually to feel better about themselves physically and emotionally towards the end of the experience. In the concluding phases of wilderness therapy the client is finally able to appreciate living a simple and primitive lifestyle and has come into balance and harmony with natural processes. This is a powerful therapeutic factor teaching lessons the client can take home after wilderness therapy. Both of these therapeutic factors, alone and in combination are reasoned to accumulate over time, and thus to be most fully manifested in the concluding phases of wilderness therapy.

Anticipated Outcomes of Wilderness Therapy

Staff at each program were asked to think of the effects of wilderness therapy in a broad sense in order to examine the underlying goals of wilderness therapy as an intervention for adolescents with problem behavior. Pattern codes which emerged from analysis of the reported outcomes are: (A) *Development of Self-Concept*, (B) *Knowledge and Skills*, (C) *Realizations to Change Behavior* (D) *Strengthened Family Relations*. The descriptive codes common to at least three of the four programs within each of these pattern codes are presented in Figure 4 and are followed by a discussion.

Development of Self Concept—Wilderness therapy represents a sense of accomplishment for the client that is concrete and real and that can be used to draw strength from in the future. This sense of accomplishment is combined with physical health and well-being, which helps clients feel better about themselves, leading to increases in self esteem and the first steps towards personal growth—which programs view as a journey lasting a lifetime. The process also teaches clients how to access and express their emotions and why talking about feelings is important. In the enhanced self-concept is a sense of empowerment and resiliency, with clients believing that if they completed wilderness therapy, they can also complete other formidable tasks. Clients leave wilderness therapy knowing that they have only just begun

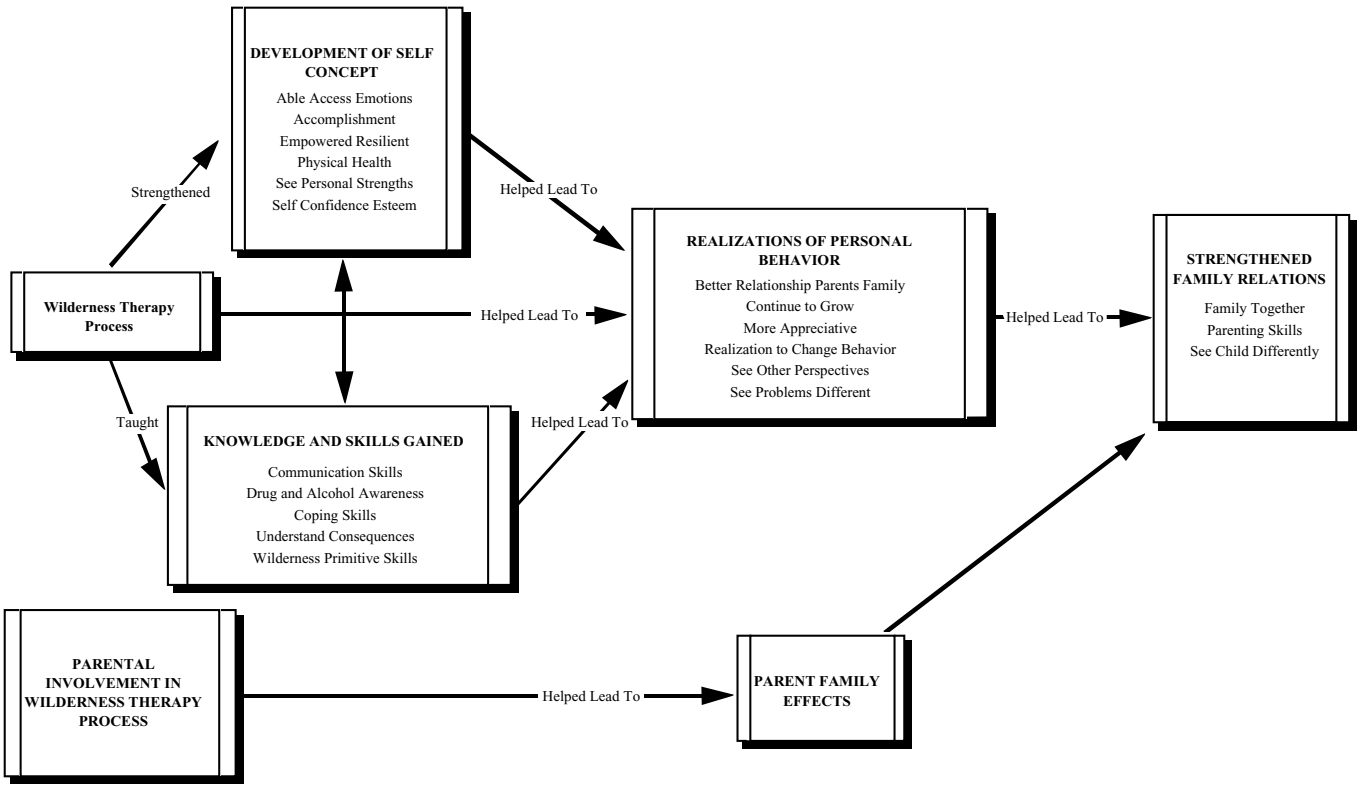

Figure 4—Pattern and descriptive codes representing reported outcomes of the wilderness therapy process.

the journey and need to continue their own personal growth process.

Knowledge and Skills Gained—Development of the self through the wilderness therapy process is combined with learning a multitude of personal and interpersonal skills, which include communication skills, drug and alcohol awareness, and coping skills. These skills help clients make better choices and when combined with the enhanced sense of self, help clients avoid negative peer and cultural influences. Clients with drug and alcohol issues complete the initial steps of the 12-Step model of recovery and begin the process of breaking the cycle of addiction. Being realistic about client relapse, parents work directly with clinical supervisors during the wilderness therapy process to help develop a relapse prevention plan to insure that the necessary support and structure is available if and when a relapse occurs. Clients have also learned to understand the consequences of their actions.

Realizations of Personal Behavior—Wilderness therapy helps clients understand changes they need and want to make after wilderness therapy. These realizations of past behavior, and proposed changes are voiced to parents during graduation ceremonies and post-trip meetings and serve as a guide for parents, staff, and follow-up institutions in helping the client maintain and realize these changes. The main realizations clients develop from the experience are the need and desire to change past behaviors, that they are being given an opportunity for a fresh start and that they must want to continue to grow. They are more appreciative of the things they have in life, such as loving and caring parents, and have learned to see other perspectives, especially those of their parents. Clients express a moral desire to reconcile and strengthen relationships with parents. They also have a different perspective of their past problem behaviors, realizing that often their behaviors were symptoms of other issues which were going on in their lives.

Strengthened Family Relations—Wilderness therapy programs do not accept clients unless the parents are committed to and take an active role in the process. This idea frames the key goal for the wilderness therapy process—a better functioning family. Parents participate in seminars that teach parenting skills and behaviors to facilitate better family functioning. Wilderness therapists work very hard with families throughout the process to insure that the family understands their role in the client's problem behaviors, and will work on establishing a structure in the home or alternate aftercare environment, to help clients continue the personal growth that has begun. Bringing the family back together that has been torn apart by the client's problem behaviors and reintegrating family structure around the client's and parents' needs are key outcomes of wilderness therapy intervention. Staff state that wilderness therapy has opened a window of opportunity for the client and family to change, and work very hard with families to take advantage of that window.

Implications for Wilderness

Wilderness therapy is a sophisticated treatment intervention based on an integrated theory of wilderness programming and eclectic therapeutic techniques, serving troubled adolescents who are not being reached by traditional therapeutic approaches. The social importance of wilderness therapy based on its emergence as an accepted treatment for troubled adolescents poses challenges and opportunities for wilderness conservation. Wilderness is increasingly being valued for more than just protected biodiversity and recreational opportunity, but also to enhance the social-economic benefits from programs for youth (Russell, 1998), and as a healing source for a growing number of emotionally and psychologically troubled adolescents (Russell and Hendee 1999).

Our data indicate a substantial and growing amount of wilderness use from at least 38 wilderness therapy programs (Russell & Hendee, 1998), which is but a small part of the much larger wilderness experience program (WEP) industry that includes at least 500 WEPs (Friese and others, 1999). Wilderness managers recognize these increases; a national survey by Gager and others (1998) found that most wilderness managers experiencing WEP use in areas they administered believed such use was increasing. These data from five known programs are initial projections extrapolated to 38 known programs and need to be validated through a survey of all wilderness therapy programs fitting the definition used in this paper.

A key issue is whether or not WEP use, including wilderness therapy, depends on designated wilderness to meet their goals. Gager and others (1998) found that a majority of wilderness managers dealing with such use believed it was not wilderness dependent, but two recent surveys of WEPs revealed that more than half the respondents said they operated in designated wilderness (Friese, 1996) and do regard their programs as depending on wilderness (Dawson, Friese, Tangen-Foster, & Carpenter, 1999). Managers' fears of WEPs identified by Gager (1998) include a need to establish new trails, overuse in areas already saturated, site impacts, large group size, lack of wilderness stewardship skills and knowledge, and conflicts with other users. Demand for wilderness use may soon overwhelm the capacities established by managers, raising difficult questions. Can we, or should we lower standards for naturalness and solitude? Can enough new areas be brought into the wilderness system to expand capacity? Is the use of wilderness for personal growth and healing of young people more important from a social and economic standpoint than commercially outfitted use, or recreational use by the public?

The use of primitive skills as a wilderness therapy tool may expand normal impacts of wilderness use, and in some places adjustments may be needed. For example, if ten clients make two fires a day for 36 days it would equal 720 fires throughout the course of one program! Already aware of these potential impacts, many programs have begun self regulating the use of fire, striving to maintain it's therapeutic value while conserving the resource. For example, Anasazi, which often operates on the Tonto National Forest in Arizona, now uses primitive methods to ignite a coal, which is then used to light propane stoves for cooking. This reduces fire scars, depletion of fuel wood, and other impacts. Catherine Freer Wilderness Therapy, which often operates in a designated Wilderness area in the Northwest, also uses primitive fire making in pre-established areas, but cooks over gas stoves to lessen their impacts.

Enhanced communication and cooperation is needed between agency managers and wilderness therapy leaders to coordinate use and address impacts with new strategies. For example, work projects might be completed by wilderness therapy programs with therapeutic effects for participants, crowded areas can be avoided during peak times, and strict leave-no-trace principles can be practiced. Better communication would also help close the gap in understanding between what are necessary and desirable practices for the benefit of wilderness. This a concern for wilderness therapy programs since they need wilderness to operate, as well as for wilderness mangers who are mandated to protect the ecological integrity of wilderness. A strengthened relationship would help deal with misperceptions about wilderness therapy, minimize impacts on wilderness and maximize benefits from wilderness therapy as a positive intervention in the lives of troubled adolescents.

References

Carpenter, J. (1998). *Program evaluation practices in wilderness therapy for youth-at-risk*. Unpublished doctoral dissertation, University of Idaho, Moscow.

Crisp, S. (1996). *International models of best practice in wilderness and adventure therapy: Implications for Australia.* (Final Report). Melbourne: Winston Churchill Fellowship.

Dawson, C. P., Friese, G. T., Tangen-Foster, J., & Carpenter, J. (1999). *Wilderness experience programs in the United States: Their dependence on wilderness*. Paper presented at the 6th World Wilderness Congress, Bangalore, India.

Friese, G., Hendee, J. C., & Kinziger, M. (1998). The wilderness experience program industry in the United States: Characteristics and dynamics. J*ournal of Experiential Education*, 21(1), 40-45.

Friese, G. T. (1996). *Inventory and classification of wilderness experience programs*. Unpublished masters thesis, University of Idaho, Moscow, ID.

Gager, D., Hendee, J., Kinziger, M., & Krumpe, E. (1998). What managers are saying and doing about wilderness experience programs. *Journal of Forestry*, 96(8), 33-37.

Glaser, B. G. (1992). E*merging vs. Forcing: Basics of grounded theory analysis*. Mill Valley, CA: Sociology Press.

Krakauer, J. (1995). Loving them, to death. *Outside*, October, 1-15.

Mathur, S. R., & Rutherford, R. B. (1994). Teaching conversational social skills to delinquent youth. *Behavioral Disorders*, 19, 294-305.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: A sourcebook for new methods*. (2nd ed.). Thousand Oaks, CA: Sage Publications.

Mulvey, E., Arthur, M., & Repucci, N. (1993). The preventment and treatment of juvenile delinquency: A review of the research. *Clinical Psychology Review*, 13, 133-167.

Richards, T., & Richards, L. (1994). Using computers in qualitative analysis. In N. Denzin & Y. Lincoln (Eds.), *Handbook of qualitative research*. Thousand Oaks, CA: Sage Publications.

Russell, K. C. (1998). The potential social and economic contributions of Wilderness Discovery as an adjunct to the Federal Job Corps program. *International Journal of Wilderness*, 4(3), 32-38.

Russell, K. C. (1999). *Theoretical basis, process, and reported outcomes of wilderness therapy as an intervention and treatment for problem behavior in adolescents*. Unpublished doctoral dissertation, University of Idaho, Moscow, ID.

Russell, K. C., & Hendee, J. C. (1999). *Wilderness therapy as an intervention and treatment for adolescents with behavioral problems*. In Watson, A. E., and Aplet, G. and Hendee, J. (Eds.). Personal, societal, and ecological values of wilderness: 6th World Wilderness Congress Proceedings on Research Management and Allocation. Volume II, Proc. RMRS-P-000. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station.

Tuma, J. (1989). Mental health services for children: state of the art. *American Psychologist*, 44: 188-199.

Interferences in Place Attachment: Implications for Wilderness

Erin K. Sharpe
Alan W. Ewert

Abstract—Previous research on place attachment has tended to focus on attachment formation, with relatively little attention given to factors that disrupt or interfere with formed place attachments. Interferences to attachments are a worthy research area for two reasons: 1) The factors of place attachment are often more salient when being disrupted, and 2) place attachment interference often leads to great uproar, making it more salient to managers and decision-makers. Expansion of the place attachment concept that considers disruptions to attachments provides a more robust framework for examining visitor behavior.

Place attachment is a concept that considers the emotive, affective elements involved in the person-place relationship (Tuan 1977). Many consider it to be an alternative framework to the more commonly used cognitive and rationally based research and decision tools, which follow the assumption that people make decisions rationally and in a linear fashion (Williams, 1989). In a similar manner, a number of growing issues in the management of wilderness point to the need for alternative frameworks for examining and managing visitor behavior. A specific example of the discord between visitor behavior and rationally based prediction models has been discussed in the satisfaction literature regarding the rational choice model. As suggested by Williams (1989), people do not maximize utility when making decisions about outdoor recreation, but instead muddle through the process. Developing a model that takes into account other influential elements of decision making, such as emotion and affect, would allow for a more holistic approach to wilderness management. Ideally, a more holistic approach would facilitate making decisions that more closely approximates the reality of motivations for many visitors.

Place attachment as a framework has the potential to be such a model and move researchers beyond what Williams and others (1992) described as the 'commodity metaphor' in wilderness research. The commodity metaphor suggests that the prevailing theoretical approach to research on outdoor recreation settings has been to focus on identifying the setting features necessary to support specific activities or desired experiences. Thus, much like consumer products, settings then become collections of features or attributes. The emphasis on manipulation and control of tangible properties of natural resources to meet recreation needs reduces recreational settings to an optimal combination of attributes for a given clientele (Williams and others 1992). While recreation research has made some gains using perspective, it has limitations. Resources are viewed as 'backdrops' for an experience, rather than an end or the 'experience' in itself (Williams 1989). Recreation settings are also viewed as interchangeable and even reproducible, as long as the alternative setting provides for the same desired attributes as the original setting. Place attachment challenges these views, choosing instead to emphasize the unique relationship that can develop between people and recreation settings.

Review of Place Attachment

Place attachment as a framework stems mainly from environmental psychology and geography and has been applied to recreation behavior with increasing frequency in the past decade. Before discussing its applications, it is worthwhile to take a brief look at the meaning of the term "place attachment." Tuan (1977) defines place as space that has been given meaning; "what begins as undifferentiated space becomes place as we get to know it better and endow it with value." Attachment used in this context can be defined as an affective relationship between people and the landscape that goes beyond cognition, preference or judgment (Riley 1992). Place attachment produces a state of psychological well-being experienced by a person as a result of the mere presence, vicinity or accessibility of the place (Mitrani 1997). Related concepts to place attachment that have also been seen in the literature include terms such as emotional investments (Hummon 1992) and emotional linkages to places (Hunter 1978).

In outdoor recreation research, place attachment is generally conceptualized as being comprised of two components: place dependence and place identity. Place dependence is "an occupant's perceived strength of association between him or herself and specific places" (Shumaker and Taylor 1983). The strength of association between a person and a place is based on two things: the degree to which the place satisfies the needs and goals of an individual, and the availability of other settings to meet the needs of the individual (Shumaker & Taylor 1983). Clearly, a person will be more likely to develop a dependence on a place when it meets a number of his/her needs and goals, especially if there are few alternative locations available that can provide for those opportunities. While place dependence does involve awareness of a location's unique and special qualities, those qualities are based on the functional and activity needs met at that place (Moore and Graefe 1994).

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Place identity, the second component of place attachment, is more closely linked to the emotional and symbolic nature of person-place relationships. Proshansky and others (1983) introduced the notion of place identity as a fundamental sub concept of self-identity, suggesting that the processes operating between place and identity are the same as between groups and identity. More recently, Twigger-Ross and Uzzell (1996) expanded Proshansky's concept, proposing that place identity is not a separate part of identity concerned with place, but that all aspects of identity have place-related implications to a greater or lesser extent. Place is considered an active part of the construction of a person's identity, representing continuity and change. For example, people use place identifications to distinguish themselves from others and as an opportunity to develop new identities. However, places also act as a referent to past selves and actions; place identities serve both as a way to distinguish difference yet maintain continuity of self.

Proshansky and others (1983) presented a number of assumptions of place identity that are particularly relevant to outdoor setting attachments. First, through personal attachment to geographic places, a person acquires a sense of belonging that gives meaning to his or her life. This sense of belonging is a function of the degree to which activities important to a person's life are centered in and around the geographic location. Second, this sense of 'centeredness' is an unselfconscious state, implying that its full meaning cannot be communicated. As a result, it is difficult to reduce or parcel out exactly how place identity and self-identity interact. Place identity is a complex structure characterized by attitudes, values, thoughts, beliefs, meanings and behaviors that are both cognitive and emotional.

Characteristics of Attached Settings

While it is difficult to predict exactly where and why individuals will develop attachments to places, some common themes have been found. Often viewed as a precursor to attachment formation is the right of an individual to occupy that space (Chawla 1992; Marcus 1992; Riley 1992). For instance, when an individual is not permitted to be in a space, such as within the context of private property, he/she generally will not form an attachment to it. Interestingly, what is more salient for place attachment is the right to be present rather than actual presence. In other words, attachments can form to places where a person may never set foot, as long as the individual perceives that a choice to enter that area.

Three other setting factors that favor attachments include the following: (a) freedom of action, (b) social interaction, and (c) setting continuity. Freedom to manipulate the surroundings to express oneself seems to favor attachment because it allows people to act in a self-determined way (Chawla 1992; Marcus 1992). Opportunities for social interaction in a place also favor attachment. It intuitively makes sense that attachments will form in places that provide for opportunities for coming together, fostering relationships, and celebrating and sharing experiences (Chawla 1992; Marcus 1992; Riley 1992). Finally, spaces that have an element of relative physical constancy and continuity are more likely to foster attachment formation. When a setting remains in the same state as when the attachment was formed, it continues to serve as an anchor for self-identity and life experience.

Wilderness and Place Attachment

In a number of ways, wilderness, as defined by the 1964 Wilderness Act, appears to be an unlikely candidate for place attachment as discussed above. While the necessary precursor to attachment is met, as wilderness is a space that is open to the public, the restrictions placed on visitors to wilderness appear as inhibiting the formation of place attachment. First, legislation restricts the visitor from altering the environment in any substantial way. This seems antithetical to the idea of freedom of action. Second, one of the prime purposes of wilderness is to provide for solitude, which counters the premise of social interaction as a necessary component for attachment formation. Yet, people do develop attachments to places in wilderness. Perhaps, the reason lies in the development of attachments to wilderness because of its designation (Williams and others 1992). In other words, people develop attachments to the *concept* of wilderness, regardless of whether they have interacted with it at all.

There may be two explanations for the seemingly counterintuitive finding. First, wilderness as legislated is different than wilderness as experienced. For example, wilderness settings may not be as restrictive as they may first appear. Clearly, visitor restrictions limit actual physical manipulation of wilderness, such as chopping down trees or picking flowers. However, while manipulation of the physical wilderness setting is low, control of the visitor over the wilderness *experience* is extremely high. In contrast to numerous other settings, the level of societal control over an individual's experience is greatly reduced. Indeed, it is the role of wilderness to serve as an antithesis to civilization that is one its most highly touted values (Hendee, Stankey, and Lucas 1990; Knopf 1988; Nash 1977). As a place where societal and role constraints are low, visitors may perceive that they can control their experience (Samdahl, 1988). This freedom is expressed in numerous ways ranging from an individual's choice of route, of a place to camp, of when to stop and swim or read a book, or even of what to talk about around the campfire.

The concept of solitude in wilderness may also be something other than what it appears. While solitude is commonly defined as being alone, Hammitt and Rutlin (1997) have found that solitude means something different for different wilderness users. For most, the wilderness experience tends to be a social experience, as 97% to 98% of users go with others to wilderness areas. As Stankey (1989) suggests, rather than complete isolation from others, solitude seems to be more a matter of "being alone together" with members of one's group. It appears that people do desire social interaction in wilderness. The opportunity to be alone together is seen by numerous groups as an essential component to facilitate social interaction. Wilderness therapy groups, student orientation programs and wilderness trips

with integrated populations are three examples of common wilderness uses with social interaction as a main objective.

As previously mentioned, people form attachments to wilderness as a category of land designation (Williams and others 1992). To explain this finding, we look to passive use values of wilderness as a possible explanation. According to Loomis and others (1999), passive use values such as existence value (valuing wilderness because it land protected from development), option value (valuing wilderness for possible future visits), or bequest value (valuing wilderness for future generations) may be more important to people than the value of actual wilderness use. It is possible that attachments can form based on the meaning these values hold for a person. There are parallels to this phenomenon in the place attachment literature for places of a religious or historical significance such as churches and monuments. In these cases, the attached place is seen as a symbol of cultural significance and meaning, and people claimed they would feel a sense of loss in the case of its disappearance or destruction (Low 1992). It is possible that people view wilderness as a similar place of significance and meaning similar to those discussed by Low (1992). Thus for a wilderness user, attachment may develop from factors of both active and passive use.

Implications of Place Attachment in Wilderness

Place attachment has three main implications in the wilderness context. First, it can be argued that visitors who are attached to the wilderness setting have a more meaningful wilderness experience. Rather than serving as a backdrop for an experience, wilderness becomes an integral component of the experience, adding another layer to the tapestry that comprises a recreation experience. Not only does this attachment contribute to the experience, it may also produce longer-lasting benefits (Walker and others 1996) and a more restorative experience (Korpela and Hartig 1996).

Second, while place attachment can enhance the wilderness experience, it can also play a role in the enduring nature of the experience. One effect is the fostering of an environmental preservation ethic. Some examples of this manifestation have been demonstrated by Chawla (1992), who found that a common thread among environmentalists was the development of an attachment to a natural setting in childhood. Similarly, Brandenburg and Carroll (1995) found that individuals who were attached to a wilderness area were more willing to make personal sacrifices that promoted the environmental protection of their place of attachment. Along with environmental awareness, personal values, and perceived control, Grob (1995) found that the intensity of emotion felt toward an environmental state was a significant predictor for environmental behavior.

Third, place attachment has potential applications as a tool to classify visitors. Indeed, there may be 'place-oriented' visitors, just as there are social or activity-oriented visitors. Place-oriented visitors, or visitors whose main motivation for visiting an area is to enjoy the place itself, have been found to have significantly higher levels of place attachment than either activity-focused or social-focused visitors (Williams and others 1992). Visitors with high levels of place attachment have also been found to be more sensitive to ecological impacts at the site of the attachment, as well as to intrusions of sight, sound and other recreationists (Williams and others 1992).

Expansion of Place Attachment Concept: Place Interference

While place attachment is a process in which people bond with places, place interference can be thought of as the converse or reversal of this process. Interference is the loss of the affective bond between a person and a place. Interferences result from noticeable changes in three aspects of the person-place relationship: the people, the process or the place (Brown and Perkins 1992). Examples in the wilderness setting include: loss of traveling companions due to changes in social situations such as death or divorce (people); loss of characteristics of the wilderness experience, such as safety or solitude (process); or loss of wilderness setting due to natural events or management policies (places). Just as with place attachment, attachment interference is holistic and multifaceted, and changes in people, processes, and place interact. For example, a management decision such as reducing group size, while intended to change the level of degradation of the "place," also clearly interacts with the "people" component of the experience. For people who feel large groups are an integral part of their wilderness experience, changes of this sort may be perceived as a negative interference.

While place attachments may develop slowly, interferences to attachment can take place quickly, with long-term effects (Brown and Perkins 1992). Person-place bonds change often and do not have the effects of a place interference, but the essential component seems to be a sense of personal control over the change. Not surprisingly, place interference is most prominent in situations where individuals with attachments have little or no control over the processes causing the interference.

Interferences to place attachments are important in the wilderness context for two reasons. First, interferences bring to the forefront the affective connection between people and places believed to exist on a day-to-day basis at a subconscious level (Proshansky and others 1983). Thus, interference can be a valuable research phenomenon for greater understanding of the processes of place attachment. Second, cases involving interferences to place attachment are most important to the wilderness manager, as these are the situations in which visitors will be most irate or distressed. Understanding the resulting effects of place interference, as well as the role that management plays in either minimizing or exacerbating interferences, is valuable information for managers.

Although individuals may react differently to interferences in place attachment, a number of principles of the effects of interferences can help guide understanding and management of place interferences in wilderness.

1) Interferences affect self-identity. To an individual, a loss of place attachment means a loss of a way to distinguish self from others and a loss of a way to relate to self in the past.

2) Interferences cause stress and a sense of loss or betrayal. In cases where interference happens rapidly, individuals

are threatened by a sense of overwhelming change. This loss is often experienced as grief. It is unclear what the outcome of this sense of loss may be. For some, it may lead to a loss of motivation for maintaining any sort of attachment with a place, and for others, it may lead to a desire to strengthen the attachment bond. Similar to the concept of psychological reactance, difference in these cases may be related to whether individuals believe they can make effective change to the interference.

3)The more sudden a change, the more difficulty there is in rebuilding attachments. For example, sudden natural disasters, incidents of crime or unanticipated management policy changes, due to the minimal foresight involved, may be more difficult to rebuild than changes implemented slowly or in increments.

4)While disruptions may be caused by isolated incidents, there may be societal trends that contribute to the likelihood of place interference. It is worth expanding on the notion that trends affect place attachments because there are a number that are actively altering attachments to places. The following is a brief list of those most salient to wilderness:

- Rapid transformation of landscape: We live in a society that has the ability to alter landscapes at an incredible rate. While we may perceive wilderness as being isolated from change, in many cases, wilderness is at high risk. In many parts of the country, lands bordering wilderness or wilderness itself are giving way to other land uses that often lead to great physical upheaval. Due to the lack of confidence people have that an area will maintain some form of landscape continuity, the benefits of forming attachments may not outweigh the sense of loss that these visitors expect when the landscape changes.
- Introduction of technology into wilderness: High-tech equipment, fabrics and gear in many ways insulate people from interaction with landscapes. While technology can make us more independent in the wilderness, it also separates us from the land in significant ways (Ewert and Shultis 1999). For example, our fabrics separate us from the 'elements,' so to speak, and our communication equipment maintains a link outside of the wilderness setting. As a result, the role of wilderness shifts closer to being a 'backdrop' for an experience.
- Changes in wilderness user: As we distance ourselves from interaction with landscapes, we move closer to becoming what Riley (1992) terms 'continual tourists.' Instead of developing relationships with landscapes we become collectors; we visit a setting, take pictures, then move on to the next setting. This trend seems to have extended to wilderness, as indicated by a decrease in the average length of wilderness visit over the last fifteen years (Watson, this proceedings). The leaning toward a more consumptive experience with this trend interferes with bond-making simply because there is less time spent immersed in a place.
- Safety risks to users: While wilderness often presents threats to safety from animals or natural causes, the perception that the real danger lies in encounters with other humans is growing. As crimes in wilderness increase in frequency and in level of media attention, visitors will be less likely to put themselves in a position that fosters place attachment, or they will simply be unable to reach the level of affection toward the wilderness that is characteristic of place attachments.

Place attachments not only augment the wilderness experience, but also can have long-term benefits such as support for resource protection, and it is important to examine how interferences can be minimized.

Management Strategies to Minimize Interferences to Place Attachment

The principles of interferences to place attachment serve as guides for the creation of strategies to manage wilderness that minimize interferences. Clearly, in some cases, fulfilling the strategy completely may lead to unacceptable levels of environmental or social impacts. The intention of these strategies is not to promote resource degradation, but to provide a perspective for decision-making that could promote and maintain place attachments.

1)Maintain as much control over the experience as possible with the visitor. Since control is the key factor separating normal changes from those that become interferences, maintaining high levels of control with visitors over the wilderness experience should minimize interferences to place attachment. Manifestations of this strategy include including visitors with attachments to the wilderness in decision-making processes and allowing for high levels of self-determination during the wilderness experiences.

2)Implement changes gradually. Publicize decisions prior to their implementation, and implement decisions in stages as best as possible. This process will provide visitors with the time and opportunity to prepare for changes.

3)Be favorable to opportunities to reconcile loss. In situations where there has been a sudden change in the person-place bond, such as in cases of sudden crimes or natural events, ritual and ceremony can help for individuals to reconcile the loss. Special events such as 'Take back the Trails' can help people move beyond the grieving stage to accepting or even bonding anew with a place.

4)Examine management decisions holistically. Be aware of how decisions may affect attachment bonds in ways that are unanticipated or unintended. Examine how decisions may affect the person, process and place involved in the attachment bond.

Place attachment, while still in the exploratory stages, has the potential to serve as a viable framework to guide research and decision-making in wilderness. The main benefit of place attachment is its ability to refocus study of visitor behavior to include the emotional and affective connections between people and places that may be missed with traditional research frameworks. Understanding how place attachments are disrupted can help expand understanding of place attachment, as well as generate strategies to maximize attachments.

References

Brandenburg, A. M.; Carroll, M. S. 1995. Your Place or Mine? The Effect of Place Creation on Environmental Values and Landscape Meanings. Society and Natural Resources. 8: 381-398.

Brown, B. B.; Perkins, D. D. 1992. Disruptions in Place Attachment. In: Altman, I. and Low, S. eds. Place Attachment. New York, NY: Plenium Press. 314 p.

Chawla, L. 1992. Childhood Place Attachments. In: Altman, I. and Low, S. eds. Place Attachment. New York, NY: Plenium Press. 314 p.

Ewert, A.W.; Schultis, J.C. 1999. Technology and backcountry recreation: Boon to recreationists or bust for management. Journal of Physical Education, Recreation, and Dance. 70(8): 23-28, 31.

Grob, A. 1995. A Structural Model of Environmental Attitudes and Behaviour. Journal of Environmental Psychology. 15: 209-220.

Hammitt, W. E.; Rutlin, W. M. 1997. Achieved Privacy in Wilderness. The International Journal of Wilderness. 3(1): 19-24.

Hendee, J. C.; Stankey, G. H.; Lucas, R. C. 1990. Wilderness Management. Golden, CO: Fulcrum Publishing. 546 p.

Hummon, D. M. 1992. Community Attachment: Local sentiment and sense of place. In: Altman, I. and Low, S., eds. Place Attachment. New York, NY: Plenium Press. 314 p.

Hunter, A. 1978. Persistence of local sentiments in mass society. In: Street, D., ed. Handbook of Contemporary Urban Life. San Francisco, CA: Jossey-Bass. 741 p.

Knopf, R. C. 1988. Human Experiences in Wildlands: A review of needs and policy. Western Wildlands. Fall 1988: 1-7.

Korpela, K.; Hartig, T. 1996. Restorative Qualities of Favorite Places. Journal of Environmental Psychology. 16: 221-233.

Loomis, J.; Bonnetti, K.; Echohawk, C. 1999. Demand for and supply of wilderness. In: Cordell, H.K., principal investigator. Outdoor Recreation in American Life: A national assessment of demand and supply trends. Champaign, IL: Sagamore Publishing. 449 p.

Low, S. 1992. Symbolic Ties that Bind: Place attachment in the plaza. In: Altman, I. and Low, S., eds. Place Attachment. New York, NY: Plenium Press. 314 p.

Marcus, C. 1992. Environmental Memories. In: Altman, I. and Low, S., eds. Place Attachment. New York, NY: Plenium Press. 314 p.

Mazumdar, S.; Mazumdar, S. 1993. Sacred Space and Place Attachment. Journal of Environmental Psychology. 13: 231-242.

Mesch, G. S.; Manor, O. 1998. Social Ties, Environmental Perception, and Local Attachment. Environment & Behavior. 30(4): 504-520.

Mitrani, M. 1997. The Role of the Physical Environment in Culture Shock. Environment & Behavior. 29(1): 64-86.

Moore, R. L.; Graefe, A. R. 1994. Attachments to Recreation Settings: The case of rail-trail users. Leisure Sciences. 16: 17-31.

Nash, R. 1977. The Value of Wilderness. Environmental Review. 3: 14-25.

Proshansky, H. M.; Fabian, A. K.; Kaminoff, R. 1983. Place Identity: Physical World Socialization of the Self. Journal of Environmental Psychology. 3: 57-83.

Riley, R. B. 1992. Attachment to the Ordinary Landscape. In: Altman, I. and Low, S. , eds. Place Attachment. New York, NY: Plenium Press. 314 p.

Samdahl, D. M. 1988. A Symbolic Interactionist Model of Leisure: Theory and Empirical Support. Leisure Sciences. 10: 27-39.

Shumaker, S. A.; Taylor, R. R. 1983. Toward a Clarification of People-Place Relationships: A Model of Attachment to Place. In: Feimer, N. R. and Geller, E. S., eds. Environmental Psychology: Directions and Perspectives. New York, NY: Praeger. 356 p.

Stankey, G. H. 1989. Solitude for the Multitudes: Managing recreational use in wilderness. In: Altman, I. and Zube, E., eds. Public Places and Spaces. New York, NY: Plenium Press. 316 p.

Tuan, Y. 1977. Space and Place: The perspective of experience. Minneapolis, MN: University of Minnesota Press. 235 p.

Twigger-Ross, C.; Uzzell, D. 1996. Place and Identity Processes. Journal of Environmental Psychology. 16: 205-220.

Walker, G.; Hull, B.; Roggenbuck, J. 1996. The Effect of Place Attachment on Recreation Benefits. Book of Abstracts for The 6th International Symposium on Society and Resource Management: Social Behavior, Natural Resources, and the Environment; 1996 May 18-23; University Park, PA. University Park, PA: Pennsylvania State Press. 264 p.

Watson, A. E. In press. Wilderness in the year 2000: Societal changes that influence human relationships with wilderness. In: McCool, S. F.; Cole, D. N.; Borrie, W. T.; O'Loughlin, J., comps. 2000. Wilderness science in a time of change conference—Volume 3: Wilderness as a place for scientific inquiry; 1999 May 23-27; Missoula, MT. Proceedings RMRS-P-0-VOL-3. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Williams, D. R. 1989. Great Expectations and the Limits to Satisfaction: A review of recreation and consumer satisfaction research. In: Watson, Alan, ed. Outdoor Recreation Benchmark 1988: Proceedings of the National Outdoor Recreation Forum; 1988 January 13-14; Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 498 p.

Williams, D. R.; Carr, D. S. 1993. The Sociocultural Meanings of Outdoor Recreation Places. In: Ewert, A. W., Chavez, D. J., and Magill, A. W., eds. Culture, Conflict, and Communication in the Wildland-Urban Interface. Boulder, CO: Westview Press. 410 p.

Williams, D. R.; Patterson, M. E.; Roggenbuck, J. W.; Watson, A. E. 1992. Beyond the Commodity Metaphor: Examining emotional and symbolic attachment to place. Leisure Sciences. 14: 29-46.

Primal Hypotheses: The Relationship Between Naturalness, Solitude, and the Wilderness Experience Benefits of Development of Self, Development of Community, and Spiritual Development

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Abstract—This paper describes what we call "the primal hypotheses," which assert positive relationships between the legislated wilderness attributes of naturalness and solitude and three broad constructs that embrace human benefits from wilderness experience reported in the literature—"development of self" (DOS), "development of community" (DOC) and "spiritual development" (SD). These hypotheses support the notion that managing wilderness for naturalness and solitude will generate wilderness experience benefits for people, in addition to meeting a legal mandate for wilderness protection. We find the hypotheses generally supported by studies reported in the literature on wilderness experience and by a limited test using data from three wilderness experience programs.

This paper describes what we call the primal hypotheses, which assert positive relationships between the legislated wilderness attributes of naturalness and solitude and three broad constructs that embrace human benefits from wilderness experience reported in the literature—"development of self" (DOS), "development of community" (DOC) and "spiritual development" (SD). We use the term hypotheses in a limited sense to suggest relationships between naturalness, solitude and the DOS, DOC and SD constructs, much like a forester would assert relationships between certain silvicultural treatments and certain forest conditions. That is, the primal hypotheses are to be considered working assumptions, standing true against general evidence, but certainly subject to further testing and confirmation. These hypotheses support the notion that managing wilderness for naturalness and solitude will generate wilderness experience benefits for people, in addition to meeting a legal mandate for wilderness protection. The primal hypotheses are relevant to the issue of whether to manage wilderness under a biocentric philosophy privileging naturalness or an anthropocentric philosophy adapting nature to human convenience and preference (Hendee and others 1990). We find the hypotheses generally supported by virtually all studies reported in the literature on wilderness experience and by our limited test using data from three wilderness experience programs with different populations.

Wilderness is appropriately understood as a human construction, a state of mind (Nash 1982). Individual perceptions of wilderness vary, as do the environments described as wilderness. However, a relatively high degree of naturalness and opportunities for solitude have been identified as two defining qualities of wilderness by the Wilderness Act of 1964. These attributes are embraced in wilderness management direction in federal agency manuals and synthesized into instructional textbook material on the subject (Hendee and others 1990). We refer to the attributes of naturalness and solitude as "primal" because they represent essential conditions that wilderness protection seeks to preserve.

Wilderness provides myriad general benefits to individuals, society and nonhuman organisms (Driver and others 1987b; Nelson 1998), but our focus here is on benefits that arise from direct, personal experience of wilderness. Driver (1996) has defined a recreational benefit as an improved condition, prevention of an undesirable condition or attainment of a desired condition. In this paper, we consider wilderness experience benefits as improved human conditions in the categories of development of self (DOS)—meaning personal benefits; development of community (DOC)—meaning interpersonal and group benefits; and spiritual development (SD)—meaning a profound sense of connection to nature, the larger universe or transcendent "Other."

A fundamental basis for wilderness stewardship, maybe especially so in the emerging ecosystem management paradigm for public lands and wilderness, is the relationship between wilderness experience benefits and the environmental settings in which they occur. One principle of wilderness management is to produce human values and benefits (Hendee and others 1990), but managers must also meet legal mandates and protect and sustain the integrity of the resource qualities that give rise to benefits. We believe it is therefore important to understand the relationships between the key wilderness attributes of naturalness and solitude and the wilderness experience benefits that we have categorized under the headings of DOS, DOC and SD.

Previous research examining relationships between environmental settings and natural resource-based recreation experiences has largely been driven by management concerns about providing a diverse set of recreation opportunities under the ROS planning framework (Clark and Stankey

In: McCool, Stephen F.; Cole, David N.; Borrie, William T.; O'Loughlin, Jennifer, comps. 2000. Wilderness science in a time of change conference—Volume 3: Wilderness as a place for scientific inquiry; 1999 May 23–27; Missoula, MT. Proceedings RMRS-P-15-VOL-3. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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1979; Driver and others 1987a). However, as Patterson and others (1998) note, the ROS framework was designed as a broad-scale guide, and more specific information about person-environment transactions is desirable. A new line of inquiry has developed that seeks to give greater importance to nature as an actor in the wilderness experience drama. This is broadening the parameters of recreation research to include the environment as a primary point of inquiry (Fredrickson and Anderson 1999). To further advance this perspective, we present these primal hypotheses, which contend that there are positive correlations between the wilderness attributes of naturalness and solitude and DOS, DOC, and SD benefits from wilderness experience.

The Primal Hypotheses

Wilderness experience benefits have been operationalized and measured using many methods, including participant observation, journal analyses, questionnaires and interviews, and analyzed with varying degrees of rigor, ranging from quantitative analyses of psychometrics and scaled continua to qualitative analyses of verbal and written responses. These studies consistently confirm that wilderness experience benefits exist, and that negative effects are virtually nonexistent (Burton 1981; Friese and others 1995; Kaplan and Kaplan 1989). We assert that these wilderness experience benefits can be generalized into three broad categories defined as development of self (DOS), development of community (DOC) and spiritual development (SD). The DOS, DOC, and SD categories logically synthesize a spectrum of previously reported outcomes from wilderness experience and provide a plausible framework for organizing reported benefits.

Development of Self

The first of the primal hypotheses asserts that wilderness naturalness and solitude are positively related to development of self (DOS) benefits from wilderness experience. Underlying this statement is the assumption that the development of self construct logically synthesizes previous research findings on "self-centered" wilderness experience benefits and provides a plausible framework for organizing them.

Among all the research findings about wilderness experience benefits, the most commonly reported are positive, self-centered effects. These consistent findings appear in so many complex variations and slightly different definitions that it prompted our use of the DOS construct as a generic category—an umbrella under which all the self-centered effects would fit (Russell and Hendee 1997). DOS encompasses personal growth (Hendee and Brown 1987), restored functioning (Kaplan and Kaplan 1989), and the numerous self-measures identified in wilderness user benefit studies, such as self-actualization (Scott 1974; Shin 1993; Young & Crandall 1984), self-concept (Gillet and others 1991; Lambert and others 1978; Schreyer and others 1990), self control/ locus of control (Marsh and others 1986; Scherl 1989) self efficacy (Cockrell 1990), reduced anxiety (Ewert 1988) and self esteem (Kaplan 1977). In a critique of 72 studies of Outward Bound® and similar wilderness experience programs, Burton (1981) noted that 59 different evaluation instruments were used to measure 41 different outcome variables, and among all the studies, enhanced self-concept was the most frequently reported benefit. However, the differences between the various psychological measures are often poorly defined or unimportant. The DOS category en-compasses these measures to reduce unnecessary complexity and to provide a plausible framework for organizing reported benefits into a usable form.

Development of Community

The second of the primal hypotheses asserts that wilderness naturalness and solitude are positively related to development of community (DOC) benefits from wilderness experience. Underlying this statement is the assumption that the development of community (DOC) construct logically synthesizes previous research findings on "community-centered" wilderness experience benefits and provides a plausible framework for organizing them.

While development of self benefits have been firmly established in the literature, somewhat less attention has been paid to interpersonal, group or community-centered effects, despite the knowledge that most wilderness use occurs in small groups of family and close friends (Hendee and others 1990; Lucas 1980)—in what Heywood (1990) describes as a spectrum ranging from primary groups to collectives. Primary groups are members with a past and future social history of interdependent relationships, such as family or friends, while collectives are combinations of individuals unknown to each other before the experience, such as clients in a wilderness experience program. Along the continuum are groups that contain varying degrees of primary and collective qualities. Wilderness experience presents a situation in which formality and role barriers are reduced, and this nurtures various forms of social cohesion such as trust, cooperation, open communication and group problem solving ability (Cheek 1981). Davis-Berman and Berman (1994) remark that even in threatening environments where activities involve risk-taking, a common set of goals fosters compatibility within the group.

The development of community (DOC) construct encompasses wilderness experience benefits accrued while passing through various stages of group development. For example, Ewert and Heywood (1991) tentatively concluded that programs operating in wilderness or comparable settings may be effective in creating well functioning and integrative groups with problem solving abilities. Arnould and Price (1993) found that river-runners developed a sense of "communitas," or feelings of communion, linkage, belonging and devotion to a transcendent group goal. DOC benefits are analogous to social identity benefits (Driver and others 1987b), and a very common DOC benefit is the strengthening or development of bonds among wilderness group members. For many wilderness experience programs aimed at the personal growth of participants, enhanced peer relationships with improved communication and teamwork—the development of community—is both a program goal and personal growth tool (Russell and others 2000).

Spiritual Development

The third of the primal hypotheses asserts that wilderness naturalness and solitude are positively related to spiritual development (SD) benefits from wilderness experience. Underlying this statement is the assumption that the SD construct logically synthesizes previous research findings on spiritual benefits from wilderness experience and provides a plausible framework for organizing them.

This third category of wilderness experience benefits refers to a deep sense of connection to all things, such as the larger universe, a higher power, nature, a feeling of oneness—what is referred to as "connection to Other," as opposed to "connection to self" (McDonald and others 1985; Riley and Hendee 1999). Spiritual development as a wilderness benefit has received little attention, although there is evidence that researchers and managers increasingly recognize the importance of moving toward an expanded land management ethic that incorporates such hard to define values (Driver and others 1996). Investigation into the spiritual benefits of wilderness experience has been hampered in the past because spiritual experiences are intensely personal and often inexpressible, and because the varied personal meanings of spirituality have made spirituality difficult to operationally define. Also, spirituality is often thought of in a religious notion, and since most wilderness and outdoor recreation research is federally funded, studies of spiritual benefits may be avoided because that might hinder approval of research methods—that is, where it is necessary to obtain Office of Management and Budget approval of proposed questionnaire and interview studies for federal funding.

While research of SD benefits is limited, some studies do report a relationship between the wilderness environment and spiritual development. McDonald and colleagues (McDonald 1989; McDonald and others 1985; McDonald and Schreyer 1991) have explored the process and content of spiritual experience in wilderness settings, and identified factors that influence the experience. Stringer and McAvoy (1992) used naturalistic inquiry to investigate the spiritual dimension of wilderness experience, suggesting several characteristics, emotions and feelings, and other factors that contributed to or detracted from spiritual experiences in wilderness. Recently, Frederickson and Anderson (1999) used a qualitative inquiry to explore spiritual inspiration as a benefit of wilderness experience and discovered, among other findings, that participants felt being in bona fide wilderness was important to spiritual inspiration. In a study of participants in a commercial wilderness vision quest program over a 10-year period, Riley and Hendee (1999) found that to "go on a spiritual journey" was a leading motive for participating, and "spirituality-connectedness" and "connection to nature" (benefits in the SD construct) accounted for 26 percent of the reported benefit comments. These vision questers also said that being in wilderness with naturalness and solitude—as opposed to a developed recreation area with roads and campgrounds—was essential to gaining the benefits they reported.

Testing the DOS, DOC, and SD Constructs and Relationships

We believe the credibility and practical utility of the DOS, DOC, and SD constructs is demonstrated by research reported in the literature on wilderness experience benefits. That is, research findings on wilderness experience benefits all seem to fit in one of the three categories. However, after developing the constructs, we tested their credibility and practical utility in a study (White 1998) that employed qualitative analysis (Miles and Huberman 1994) of post-experience interview and focus group data collected from participants in three wilderness experience programs in Montana, Idaho and Oregon in the summer and fall of 1997 (N = 44). The three wilderness experience programs included: 1) two "Wilderness Discovery" six-day backpacking trips with students from the Trapper Creek Federal Job Corps Center, operated by the U.S. Forest Service in Darby, Montana (Russell and Hendee 1997); 2) "IN IDAHO," a University of Idaho new student orientation program with a six-day wilderness backpacking experience (Farmer 1999); and 3) a "Wilderness Vision Quest Experience" class at the University of Idaho, featuring three weeks preparation and a six-day wilderness experience with a four-day and four-night solo fast (Riley 1997).

We found that the DOS, DOC, and SD constructs captured and discriminated between all the self-reported benefits generated by participants' responses to the open-ended question, "In your own words, what were the most important benefits you gained from this experience?" Similar responses were coded into specific subcategories for each wilderness experience program. This data reduction process served to sharpen, sort, focus and organize (Miles and Huberman 1994) the interview data. Next, three separate focus groups were conducted with the participants from each program that provided the opportunity for the members to check the researcher's interpretations, and to synthesize and clarify meaning.

After the in depth within-case analysis, benefit subcategories were compared across the three programs. Through a cross-case analysis the DOS, DOC, and SD categories emerged. The purpose of this analysis was to use empirical data to test the initial assumption that benefits from wilderness experience can be logically grouped into to the DOS, DOC, and SD categories. The credibility of the constructs was further demonstrated when multiple coders from the research team reviewed the analysis and established a high inter-coder reliability index.

As an initial test of the hypothesized relationships between the benefit categories and wilderness naturalness and solitude, the participants were asked to rate the importance of both naturalness and solitude to gaining the specific benefits they reported, as well as their perception of what effect a less natural environment or less opportunities for solitude would have on their ability to gain their specific benefits. Descriptive statistical analysis of Likert-type scales demonstrated that these participants from three different wilderness experience programs believed naturalness and solitude were important to gaining their DOS, DOC and SD benefits (table 1). Participants also said that a less natural setting—such as a more developed recreation area with roads, structures and facilities—or fewer opportunities for solitude—such as more frequent contacts with other persons and less alone time—would have negatively affected their ability to gain the specific benefits they reported (table 2). Therefore, initial evidence from a limited convenient sample supports our assertion

Table 1—Mean scores from participants in three wilderness experience programs reflecting their perceived importance of naturalness and solitude to gaining the specific benefits they reported (coded as DOS, DOC, and SD benefits)[a].

	Wilderness Discovery (n = 19)		In Idaho (n = 11)		Vision Quest class (n = 14)	
	Naturalness	Solitude	Naturalness	Solitude	Naturalness	Solitude
DOS	1.67	1.08	2.00	1.67	2.08	2.46
DOC	2.00	–0.56	0.50	2.17	0.87	2.00
SD	3.00	3.00	–	–	1.50	3.00

[a]Seven point Likert-type scale ranging from –3 "extremely unimportant" to +3 "extremely important." Means are from focus group consensus rankings of the importance of naturalness and solitude to specific benefits reported that were coded as DOS, DOC, and SD.

Table 2—Mean scores from participants in three wilderness experience programs reflecting their perceived effect of reduced naturalness and reduced solitude on their ability to gain the specific benefits they reported (coded as DOS, DOC, and SD benefits)[a].

	Wilderness Discovery (n = 19)		In Idaho (n = 11)		Vision Quest class (n = 14)	
	Naturalness	Solitude	Naturalness	Solitude	Naturalness	Solitude
DOS	–2.35	–2.20	–2.67	–2.11	–2.00	–2.32
DOC	–1.82	–1.76	–1.64	–1.82	–1.45	–1.91
SD	–3.00	–3.00	–	–	–2.67	–3.00

[a]Seven point Likert-type scale, ranging from –3 "extremely reduced" to +3 "extremely enhanced." Means scores are from interview participants from each program who reported specific benefits later coded as DOS, DOC, or SD.

that naturalness and solitude are positively related to benefits classified as DOS, DOC, and SD.

Conclusions

We found that the DOS, DOC, and SD constructs are consistent with wilderness experience benefits reported in the literature, and they provided a useful framework for our study in which we tested the primal hypotheses with data from participants in three wilderness experience programs. We found support for the hypotheses, that is positive relationships were affirmed between naturalness and solitude and development of self (DOS), development of community (DOC) and spiritual development (SD) benefits—although our test was limited to 44 participants in three programs.

We think the DOS, DOC, and SD constructs provide a useful wilderness benefits classification scheme. But further validation is surely needed, as well as other studies investigating the relationships between the three benefit categories and the wilderness attributes of naturalness and solitude. Further, although there are abundant studies documenting development of self benefits from wilderness experience, more research is needed to clarify development of community benefits, and much more inquiry is needed into spiritual development benefits.

Management Implications

The primal hypotheses and our limited study support the notion that a biocentric wilderness management focused on maintaining the naturalness and solitude of the wilderness environment will produce benefits for people experiencing those attributes. Wilderness stewards working within ecosystem management and utilizing limits of acceptable change (LAC) and associated planning frameworks (such as ROS/WROS; VERP; VIM), may find the DOS, DOC, and SD constructs to be a useful tool for classifying wilderness experience benefits into generic categories. This could facilitate a benefits-based management approach (Driver 1996), under which managers would catalog the types of benefits to be gained experiencing attributes on lands under their stewardship, and then focus management to provide them. Under the primal hypotheses, wilderness lands that are managed to retain high levels of naturalness and solitude, just as we believe the Wilderness Act of 1964 requires, and expressed in a biocentric management philosophy should produce development of self (DOS), development of community (DOC), and spiritual development (SD) benefits from wilderness experience.

References

Arnould, E. J.; Price, L. L. 1993. River magic: Extraordinary experience and the extended service encounter. Journal of Consumer Research. 20(1): 24-45.

Burton, L. M. 1981. A critical analysis and review of the research on Outward Bound and related programs. Unpublished Doctoral Dissertation. The State University of New Jersey.

Cheek, N. 1981. Social cohesion and outdoor recreation. In: Kelly, J. ed. Social benefits of outdoor recreation. Champaign-Urbana, IL: University of Illinois Department of Leisure Studies: 18-27.

Clark, R.N., and Stankey, G.H. 1979. The Recreation Opportunity Spectrum: A framework for planning, management and research. General Technical Report PNW-98. Seattle, WA: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest Range Experiment Station.

Cockrell, D. 1990. Changes in self-efficacy through outdoor skills instruction. In: Passineau, J.F.; Easley, A.T.; Driver, B.L., eds. The use of wilderness for personal growth, therapy, and education. General Technical Report RM-193. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 35-37.

Davis-Berman, J.; Berman, D. 1994. Wilderness therapy: Foundations, theory and research. Dubuque, IO: Kendall/Hunt.

Driver, B. L. 1996. Benefits-driven management of natural areas. Natural Areas Journal. 16: 94-99.

Driver, B. L.; Brown, P. J.; Stankey, G. H.; Gregoire, T. G. 1987a. The ROS planning system: Evolution, basic concepts, and research needed. Leisure Sciences. 9: 201-212.

Driver, B. L.; Dustin, D.; Baltic, T.; Elsner, G.; Peterson, G. 1996. Nature and the human spirit: Toward an expanded land management ethic. State College, PA: Venture Publishing.

Driver, B. L., Nash, R., & Haas, G. 1987b. Wilderness benefits: A state-of-knowledge review. In: Lucas, R. ed. Proceedings of the National Wilderness Research Conference: Issues, state-of-knowledge, future directions. General Technical Report INT-220. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 294-319.

Ewert, A. 1988. Reduction of trait anxiety through participation in Outward Bound. Leisure Sciences. 10(2): 107-117.

Ewert, A.; Heywood, J. 1991. Group development in the natural environment: Expectations, outcomes, and techniques. Environment and Behavior. 23(5): 592-615.

Farmer, P. 1999. "IN IDAHO" - Design, implementation and evaluation of a new student orientation program with wilderness experience at the University of Idaho. Unpublished Doctoral Dissertation. Draft available from the Wilderness Research Center, University of Idaho, Moscow, ID.

Fredrickson, L. M.; Anderson, D. H. 1999. A qualitative exploration of the wilderness experience as a source of spiritual inspiration. Journal of Environmental Psychology. 19: 21-39.

Friese, G.T.; Pittman, J.T.; Hendee, J.C. 1995. Studies of the use of wilderness for personal growth, therapy, education, and leadership development: An annotation and evaluation. Moscow, ID: University of Idaho, Wilderness Research Center. Available in electronic format from wrc@uidaho.edu.

Gillet, D.; Thomal, B. P.; Skok, R.; McLaughlin, T. F. 1991. The effects of wilderness camping and hiking on the self-concept and environmental attitudes and knowledge of twelfth graders. Journal of Environmental Education. 22(3): 33-44.

Hendee, J.C.; Stankey, G.; & Lucas, R. 1990. Wilderness management. Golden, Co: Fulcrum Press.

Hendee, J. C.; Brown, M. H. 1987. How wilderness experience programs work for personal growth, therapy and education: An explanatory model. Paper presented at the 4th World Wilderness Congress, Estes Park, CO.

Heywood, J. L. 1990. Collective social groups in the wilderness: Problems and prospects. In: Easley, A.T.; Passineau, J. F.; Driver, B.L. ed. The use of wilderness for personal growth, therapy and education. General Technical Report RM-193. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 23-25.

Kaplan, R. 1977. Patterns of environmental preference. Environment and behavior. 9: 195-216.

Kaplan, R.; Kaplan, S. 1989. The experience of nature: A psychological perspective. Cambridge: Cambridge University Press.

Lambert, M. J.; Segger, J. F.; Staley, J. S.; Spencer, B.; Nelson, D. 1978. Reported self-concept and self-actua lizing value changes as a function of academic classes with wilderness experience. Perceptual and Motor Skills. 46: 1035-1040.

Lucas, R. 1980. Use patterns and visitor characteristics, attitudes and preference in nine wildernesses and other roadless areas. Research Paper INT-253. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

Marsh, H. W.; Richards, G. E.; Barnes, J. 1986. Multi-dimensional self-concepts: The effect of participation in an Outward Bound programme. Journal of Personality and Social Psychology. 50: 195-204.

McDonald, B. 1989. The outdoors as a setting for spiritual growth. Women in Natural Resources 10(2): 19-23.

McDonald, B.; Guldin, R.; Wetherhill, R. C. 1985. The spirit in the wilderness: The use and opportunity of wilderness experience for spiritual development In: Lucas, R. ed. Proceedings of the National Wilderness Research Conference: Issues, state-of-knowledge, future directions. General Technical Report INT-220, 294-319. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

McDonald, B. L.; Schreyer, R. 1991. Spiritual benefits of leisure participation and leisure settings. In: Driver, B.L.; Brown, P.L.; Peterson, G.L. eds. Benefits of Leisure. State College, PA: Venture Publishing: 179-193.

Miles, M. B.; Huberman, A. M. 1994. Qualitative data analysis. 2nd ed. Thousand Oaks, CA: Sage Publications.

Nash, R. 1982. Wilderness and the American Mind. 3rd ed. New Haven: Yale University Press.

Nelson, M. 1998. An amalgamation of wilderness preservation arguments. In: Callicott, J. B.; Nelson, M. eds. The great new wilderness debate. Athens, GA: The University of Georgia Press: 154-200.

Patterson, M. E.; Watson, A. E.; Williams, D. R.; Roggenbuck, J. R. 1998. An hermeneutic approach to studying the nature of wilderness experiences. Journal of Leisure Research. 30(4): 423-452.

Riley, M. 1997. Wilderness vision quests: They tap the spiritual values of wilderness. Women in Natural Resources (18)1: 11-13.

Riley, M. F.; Hendee, J. C. 1999. Wilderness vision quest clients, motivations and reported benefits from an urban-based program 1988-1997. In: Watson, A.E.; Aplet, G.H.; Hendee, J.C., comps. Personal, societal and ecological values of wilderness: Sixth World Wilderness Congress Proceedings on Research Management, and Allocation, volume II; Bangalore, India. Proc. RMRS-P-4. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest Research Station.

Russell, K.C.; Hendee, J.C.; Phillips-Miller, D. 2000. How wilderness therapy works: Theoretical foundation, process and outcomes of wilderness therapy as an intervention and treatment for adolescents with behavioral problems and addictions. In: Cole, David N.; McCool, Stephen F. Proceedings: Wilderness Science in a Time of Change. Proc. RMRS-P-000. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Russell, K. C.; Hendee, J. C. 1997. Testing Wilderness Discovery: A wilderness experience program for youth-at-risk in the Federal Job Corps. Technical Report 24. Moscow, ID: Idaho Forest, Wildlife and Range Experiment Station.

Scherl, L. M. 1989. Self in wilderness: Understanding the psychological benefits of individual-wilderness interaction through self-control. Leisure Sciences. 11(2): 123-135.

Schreyer, R.; Williams, D. R.; Haggard, L. 1990. Episodic versus continued wilderness participation-implications for self-concept enhancement. In: Easley, A.T.; Passineau, J. F.; Driver, B.L., eds. The use of wilderness for personal growth, therapy and education. General Technical Report RM-193, 23-25. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 23-25.

Scott, N. R. 1974. Toward a psychology of wilderness experience. Natural Resources Journal. 14: 231-237.

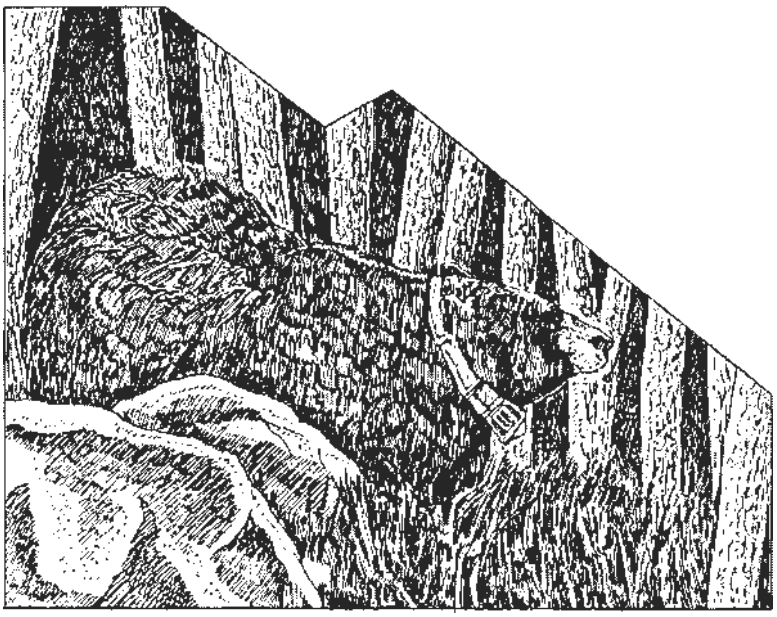
Shin, W. 1993. The understanding of the forest campers' attitudes and their self-actualization in relation to quality of forest resources. Journal of Korean Forestry Society. 82(2): 107-122.

Stringer, L. A.; McAvoy, L. H. 1992. The need for something different: Spirituality and wilderness adventure. Journal of Experiential Education. 15(1): 13-20.

White, D. D. 1998. Primal hypotheses: The relationships between naturalness, solitude and human benefits from wilderness experience. Unpublished Masters Thesis. University of Idaho: Moscow, ID.

Young, R. A.; Crandall, R. 1984. Wilderness use and self-actualization. Journal of Leisure Research. 16(2): 149-160.

5. Management of Science in Wilderness



Identifying Research Needs for Improved Management of Social Impacts in Wilderness Recreation

Gordon R. Cessford

Abstract—This paper summarizes the social impact research and information needs derived from a workshop of over 50 recreation management staff in the New Zealand Department of Conservation. The overall objective was to establish the basis for developing a research plan underpinning social impact management. After scoping the diversity of social impact issues, the workshop identified five main social impact themes that categorized social impacts as being caused by management actions, intergroup encounters and conflicts, intragroup encounters and conflicts, inappropriate uses and behaviors, and off site intrusions. Exploration of these social impact themes yielded numerous research questions, which were grouped under identifying demand characteristics, defining social values, understanding and managing recreation conflict, and evaluating management outcomes. A social impact research framework is proposed based on interactions between specifically defined places, physical and social human effects, and social values.

Following a successful workshop on the physical impacts of visitors on natural and historic resources (Cessford 1997, Cessford and Dingwall 1997), the New Zealand Department of Conservation (DOC) held a workshop on the social impacts of visitors on the recreation experiences and sociocultural values of others (Wellington, May 13-18, 1998). Its main purpose was to identify DOC research and information needs in this particular area of conservation management. To achieve this result, around 50 participants were selected from the DOC staff required to manage and research visitor impact problems, along with selected park management staff from the local government sector. From the United States, Alan Watson of the Aldo Leopold Wilderness Research Institute gave a comprehensive social science perspective, while Laurel Boyers of Yosemite National Park provided practical management experience in deriving research needs under high-pressure social impact conditions. This represented a new approach to identifying the research and information needs for the management of New Zealand's growing and diversifying outdoor recreation and tourism sector in national parks and similar protected areas.

To set the scene, presentations were made on the latest legislation and policy for DOC's visitor impact management responsibilities (Department of Conservation 1996, 1998). State-of-knowledge summaries on social impacts and management processes were presented, social impact definitions were discussed, and several New Zealand case studies of issues and solutions were also explored. Participants contributed through directed discussions in working groups, which over the three days of the workshop:

- identified the diversity of social impact issues that they had encountered;
- explored five summary social impact themes; and
- determined four research and information themes for improved social impact management.

Social Impacts and Social Values

Before summarizing these workshop findings, it is helpful to briefly define some key terms. The "social impacts" can be considered human effects on physical and social conditions that detract from associated social values. What are these social values? In a wilderness management context, the social values associated with human activities at places have two interrelated but distinct components—recreation experiences and sociocultural perspectives.

The social values associated with recreation experiences are the outcomes anticipated from engaging in chosen activities at chosen places. These can form the basis for the specific recreation management priorities at those places. They relate directly to active on-site participation by visitors in recreation activities. The social values associated with sociocultural perspectives have a different context. They relate to the wider values that people attribute to different places for different reasons, derived from the natural, historic and cultural heritage features present at or associated with places. They can form the basis for specific conservation and heritage management priorities at those places. However, they may not necessarily involve any direct site visit and are commonly off-site perspectives.

In both cases, the on-site activities of recreation visitors can have major effects on the social conditions prevailing at a site, some of which may represent serious impacts on the desired social values associated with those sites. With this distinction acknowledged, the remainder of this paper summarizes the social impact themes identified; presents the main research and information conclusions derived from these themes; and proposes the basis for a social impact research plan.

Social Impact Themes

When exploring social impact issues, workshop participants paid particular attention to a variety of factors. These

In: McCool, Stephen F.; Cole, David N.; Borrie, William T.; O'Loughlin, Jennifer, comps. 2000. Wilderness science in a time of change conference—Volume 3: Wilderness as a place for scientific inquiry; 1999 May 23–27; Missoula, MT. Proceedings RMRS-P-15-VOL-3. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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included the effects of management actions, different cultural and spiritual perspectives, individual and group values, evaluations of other groups, expectations and satisfactions, perceptions of crowding, mode of transport, motorized versus non-motorized activities, applications of new technology, inter- and intra-activity conflict, values and ideology, adjacent land uses, intrusive activities, different setting contexts and commercial involvement in recreation activities. Some of these issues were considered inherent in all social impact questions (for example, social-cultural perspectives; individual and group values; visitor expectations and satisfactions). However, five distinct but overlapping social impact themes were consistently identified. These were social impacts generated by:

- Management intervention
- Intergroup encounters and conflict
- Intragroup encounters and conflict
- Inappropriate uses and behaviors
- Off-site intrusions

Working group findings are reported fully in the workshop summary and proceedings (Cessford 1999a,b). Summary descriptions of these findings are provided below for each of the social impact themes, including the initial research and information issues raised.

Management Intervention

Social Impact Issues—Management intervention aims to change the physical conditions of sites and the social conditions of related recreation experiences. These changes will interact to directly or indirectly affect the types of physical and social impacts that might occur. Direct effects may be from deliberate management choices providing for specific recreation outcomes, such as provision of certain facilities or imposition of particular use-rationing approaches. Any impacts from these actions will be limited to some visitors, while others will regard the outcomes as positive. Indirect effects may arise from management actions targeting other non-recreation objectives such as heritage conservation, visitor safety or facility maintenance. Impacts here may also reflect different visitor perceptions of the management techniques themselves, based on different attitudes toward issues like perceived recreation freedom, degree of management regimentation, appropriateness of user charges and commercial provision of recreation opportunities. In all cases, an array of direct and indirect, planned and unplanned, and positive and negative consequences will result from management actions. Managers need a good understanding of all such consequences.

Consideration of these social impact issues emphasized the effects from use restrictions, imposing charges for access or use, changes in access provisions, provision of information services, provision of more on-site staff presence, the balance of commercial and noncommercial uses, and other management operations (such as pest control). These were summarized into four main categories of management intervention contributing to social impacts:

- visitor use restrictions and controls
- provision of visitor facilities and services
- conservation operations
- applications of information services

The other context for management-derived impacts concerned the effects of management inaction. Social impacts can accelerate and diversify when managers are unaware of changing social and physical conditions. Even if managers are aware, they may lack the time, resources or knowledge to take some action. This highlights some of their important monitoring and priority-setting information needs.

Initial Information Needs—The main questions pointed to the need for assessment and evaluation, determining what are the social, physical and management outcomes of different management interventions. Of particular interest was how these interventions impact differently on different visitor groups. Key questions include: What are the attitudes of visitors toward different management options? What is the relative effectiveness of different interventions? How effective are visitor satisfaction measures in management evaluation? How important to evaluating management success is a clear specification of management objectives? Of secondary importance were a group of research needs dealing with the flexibility available to managers to develop new or different management options under current operating frameworks (such as funding, legislation, policy and partnerships). This involves research on management processes and their interactions with legislation and policy development.

Inter-Group Encounters and Conflicts

Social Impact Issues—The social impacts among recreationists and with other stakeholders usually involves intergroup conflict due to negative perceptions of the presence, behavior and characteristics of other people. Conflicting groups are typically of different activity types that are sharing sites and competing there for access to their desired recreation experiences. The most common example is of motorized versus non-motorized activities.

There is also growing recognition of wider social impact perspectives including other stakeholders: locals versus tourists, rural versus urban, management versus users, private versus public, commercial versus noncommercial and different cultural perspectives. The sources of these impacts may range from the effects of direct physical contact with people on-site to indirect and abstract disapproval felt from an off-site perspective about certain other groups of people using a particular setting. Some reflect common values held in relation to traditional versus nontraditional use; resident versus nonresident use; national versus international visitor use; and rural versus urban use. The following examples of intergroup conflict issues were considered:

- commercial versus noncommercial uses
- conflict and competition between different activity groups
- varying degrees of compliance with regulations
- different perceptions of ownership and attachment to the activity and setting

Initial Information Needs—Two types of research need arose here. First, developing an understanding of recreation conflict processes for achieving clearer problem definition. Research here can improve the identification of those factors contributing most to how different visitors evaluate each other in different situations, answering the basic question—what is this conflict really all about? Second, research on

assessing the effectiveness of information approaches, for evaluation of the best options for solutions. Using information to influence visitor choice of particular activities and sites, and how they evaluate other visitors, is commonly considered a priority means to address conflict issues. How effective are different information strategies and techniques in preventing or reducing conflict?

Intra-Group Encounters and Conflicts

Social Impact Issues—Principles of intergroup conflict also apply at a more subtle level within an activity group. Specific attention to intragroup conflicts gives a more detailed perspective on the underlying causes of all social impacts. The most common perspective on intragroup conflict has been through a focus on recreation crowding. This has little to do with absolute numbers or use-levels; rather, it reflects how different use-levels and behavior-styles within an activity are interpreted as being appropriate. Put simply, intragroup conflict may arise between people involved in the same activity, but who differ significantly in terms of the primary qualities they expect to experience. Conflict can arise where others, through their perceived or real behaviors, are attributed with having different values for these qualities. The following examples of intragroup conflict issues were considered:

- types of inappropriate behavior
- crowding and conflict perceptions
- different values and attachments for settings and activities
- traditional versus nontraditional cultural use
- different activity orientations
- degree of fee compliance

Initial Information Needs—The main information needs identified for managing the social impacts of intragroup conflicts were based on the need to improve understanding of inappropriate behavior and crowding. This was based on defining and scoping different behavioral and crowding problems, and understanding both the common contributing factors applying in most cases, and the unique factors specific to certain activity types or sites. How do these factors relate to on-site management for specific recreation experience goals? Are these goals made apparent to visitors prior to and during their visits?

Inappropriate Uses and Behaviors

Social Impact Issues—Some types of activity have more obtrusive effects in both intergroup and intragroup conflict situations. These are the activities, use-styles and behaviors most likely to consistently generate social impacts with those others that consider such effects "inappropriate." Specific focus on what comprises these more "intrusive" impact effects is important, because it can allow better anticipation of the future conflicts likely to arise in changing recreation situations. It can also aid prediction of the likely outcomes from management actions taken specifically to reduce particular conflict-generating effects. The following examples of inappropriate uses and behaviors were considered:

- use of new technology
- motorized vehicle use for recreation
- motorized vehicle use for access
- commercial competitive events
- other outdoors events
- antisocial or criminal behavior

Initial Information Needs—Research discussions here emphasized the need to improve understanding of interactions between different visitors, activity styles, place and activity dependence, group values and individual values and perceptions of place. What makes some recreation activities, experiences and visitors more susceptible (or tolerant) to impacts than others? What visitor characteristics and behaviors have disproportionately greater impact effects? General review research was favored here. Also emphasized was a need for research that provided processes for systematically defining social and environmental values at defined places. This would also require investigation of how people's values and sense of place could change over time. Such information could provide an improved management capacity for specifically identifying elements of social and physical quality, and the appropriate and inappropriate behavior types, in different situations and sites.

Off-Site Intrusions

Social Impact Issues—Significant social impacts can arise due to human activity on the land, water or airspace beyond direct management control. Aircraft overflights, activities on lakes and rivers, and activities on adjacent lands are often managed differently from the experiences being managed for on the conservation lands. Intrusions by effects such as noise, light and the presence of "inappropriate" activities, developments or land-uses can have negative effects on recreation experiences. In addition, off-site perspectives of the on-site recreation activities and management can lead to wider impacts on sociocultural values in society, which have implications for on-site management. This represents the broader perspective of social impacts beyond simple on-site competition. The following examples of off-site social impact issues were considered:

- inconsistent management controls on adjacent areas of land, air and water
- sociocultural values for places
- visitor expectations generated from media, marketing and promotion activities
- nonuser perspectives and nonuse issues
- change in socioeconomic conditions
- pressures from public participation processes

Initial Information Needs—The basic questions raised here emphasized the importance of identifying interactions between off-site and on-site factors, defining the relationships and components, and determining means to alter these as required. However, most of the social impact issues raised here will already be covered by general questions in recreation conflict research. Particular attention was paid to the positive value in specifically engaging in off-site management actions to influence on-site conditions. The main questions here related to information use, and which techniques were most effective.

Research and Information Themes

The main research and information themes were derived from the workshop discussions on the preceding social impact themes. Although these themes are described individually below, they are all interrelated and presented in no particular order. The main research and information themes were:

1. Identifying recreation demand characteristics
2. Defining social values in recreation places
3. Identifying and managing recreation conflict
4. Evaluating management outcomes

Identifying Recreation Demand Characteristics

Accurate data on visitor numbers, characteristics and motivations represents the essential baseline information required for achieving various visitor management objectives. With improved expressions of these elements, research and management solutions derived to address the more complex social impact issues can be more effectively applied. The outcomes of site management for recreation experiences will be most often measured in terms of participation levels and indicators of visitor satisfaction. Neither of these measures can be applied effectively at visitor sites if there is not reliable record of visitor numbers or refined knowledge of what visitors want from their site visits.

The key question here is what are the volumes, patterns and trends of demand for different recreation opportunities? Table 1 highlights the main types of research and information investigations required.

Defining Social Values in Recreation Places

A consistent theme throughout the workshop was that the social values being provided and protected at places managed for visitor use need to be better identified and characterized, and specified as management objectives. Improved specification of site-related management objectives will assist in assessing the likelihood of social impacts developing, the most effective management interventions that may be applied for them and the most appropriate indicators and standards that may be required for monitoring. However, it was clear that there are significant knowledge gaps in understanding the sociocultural and recreation-experience values, their associations with specific places and their practical application to defining site-specific social management conditions. The Recreation Opportunity Spectrum (ROS) was discussed as one example of a framework that goes part way toward fulfilling this need, but workshop participants considered this framework applied at a level too coarse for effective site-specific management actions and monitoring processes. While the opportunity-class criteria provide the physical and social background setting for more site-specific visitor-management areas, they require more explicit and site-specific management objectives. To reveal where social impacts are occurring, or might be anticipated, managers need a systematic framework for clearly identifying the particular sociocultural and recreation-experience values they are managing for at different sites within the wider management frameworks such as the ROS.

The key question here is how can we define, classify and specify the different social values associated with different recreation settings? Table 2 highlights the main types of research and information investigations required.

Identifying and Managing Recreation Conflict

When the desired sociocultural and recreation-experience values at particular places can be defined and specifically managed for, the main social impact issues that occur will arise in two ways. First, where the recreation experience opportunities provided by management, and the associated sociocultural values they might also be protecting, are inconsistent with those that visitors (or non-visitors) may expect. Second, when the presence and behavior of other visitors prevent these recreation experiences from being achieved as expected, or compromise the sociocultural values held.

Table 1—Research areas for identifying recreation demand characteristics.

Indicative information areas	Indicative research areas
* Visitor numbers * Demographics * Use patterns * Visitor wants/needs * Use/activity trends * Projections/modelling * Resource demand * Resource supply * Monitoring methods	* Visitor counting technologies. Both the innovation of new counter hardware applicable to a variety of locations, and new software applications for managing count data. * Visitor counting systems. Modelling for strategically deploying counters to allow extrapolation of counts across wider visitor systems, and for monitoring trend indicators. * Visitor characteristics, trends and projections. Develop methodologies for the systematic recording of standardized demographic indicators in visitor monitoring programs, and in any complementary visitor survey research. * Visitor motivations and expectations. Summarize the state-of-knowledge on visitor motivations for recreation participation in outdoor settings, including reference to generic motivations; those motivations more specific to different activities, visitor-groups and site categories; and how these relate to visitor expectations. * Site-dependence and supply. Identify the relative site dependence of different visitor/activity groups, and review these needs relative to the current and potential supply of appropriate recreation opportunities.

Table 2—Research areas for defining social values in recreation places.

Indicative information areas	Indicative research areas
Social values Value classifications Norm definitions Site quality Sense of place values Activity attachment Place attachment Activity/site links Visitor preferences	* Defining social values. Summarize the state-of-knowledge on systematically distinguishing and defining recreation-experience and sociocultural values, particularly within recreation management frameworks. * Defining sense-of-place. Investigate the nature of "place" values associated with defined sites (e.g. sense of place, attachment, ownership, or dependence), and how these may vary between different activity, visitor and non-visitor groups. * Social value classification. Investigate options for generalizing and classifying shared values, and for distinguishing those other values unique to certain groups. Identify the similarities and differences in social value patterns among different groups. * Evaluate social norm applications. Summarize the principles of social norm definition and their practical utility for providing a characterization of different social values. * Linking values to expectations. Summarize the state-of-knowledge on any relationships between the social values attached to places, and activities at places, and the formation of visit expectations for those places. * Defining social value management objectives. Review management processes for specification of site-specific management objectives that provide for particular recreation-experience opportunities, and protecting particular sociocultural values.

Having an explicit set of experience-based management objectives for any given site or area will make these social impact inconsistencies more transparent, and thus more readily predictable and manageable. Moreover, when the other social values associated with particular places can be specified, other social impact issues that can arise will be more readily addressed. As demonstrated by McCool and Cole (1997), all of the main planning frameworks for managing recreation experiences and social impacts depend on a baseline definition of such management objectives—leading to the specification of particular social and physical conditions as indicators, with associated standards.

The main research needs here relate to how people determine that their sociocultural values and/or preferences for recreation-experiences are compromised. Perceptions of conflict and crowding appear the main ways in which these compromises are negatively perceived. However, people demonstrate various coping strategies (such as rationalization, product shift, displacement) that limit the utility of simple cause-effect relationships in understanding and managing the generation of social impacts. Moreover, different visitors, visitor groups, activity groups and non-visitors all have different value perspectives. How can we equitably manage sites used by and valued by a diversity of people?

Without taking account of such intervening processes and variables, management may fail to identify progressive erosion of more impact-sensitive sociocultural and recreation-experience values. These can be replaced by others more impact-tolerant in a process often termed "recreation succession". The generation of social impacts is a perceptual process with a number of stages and intervening variables. In the context of an overall visitor management framework, improved understanding of how these elements interact, and some pragmatic "best-practice" specification of what assumptions can be reasonably made, will promote improved management to prevent or reduce social impacts.

The key question here is how are the sociocultural and recreation-experience values compromised by people's presence and behavior in recreation settings? Table 3 highlights the main types of research and information investigations required.

Evaluating Management Outcomes

Managers need to look at the outcomes of recreation management actions directed at social impact issues, including regulations and controls, facility and service provision and the consequences of non-recreation management actions directed at other conservation objectives. Management actions influence the social and physical conditions at sites used to achieve different recreation experiences. These may be direct actions aimed specifically at managing some social impact issue, or indirect actions taken for some other purpose. By taking or not taking different actions, management may have both positive and negative affects on different recreation experience opportunities. Managers first need to know if the actions they are taking are achieving the required outcomes. Second, they need to know what problems arise from the social and physical changes they create. To better distinguish these positive and negative outcomes, managers must have first specified their objectives for taking those specific actions. It is important to have distinguished these specific "action-objectives" from the wider management objectives prevailing at a site-level.

Developing more accurate means of assessing visitor satisfaction will be a key to evaluating management effectiveness. This was a strongly expressed information need from workshop participants. Where notable levels of dissatisfaction are revealed at sites, it is likely that the social and physical conditions created by management actions are inconsistent with visitor expectations. Where this dissatisfaction represents visitor expectations that are fundamentally inconsistent with management objectives for a site, the problem may result from managers not effectively informing visitors of the appropriate social and physical conditions at the site. Where this dissatisfaction represents compromised visitor experiences due to inadequate services and facilities, or negative perceptions of other visitors, specific on-site management actions may be required.

The strategic use of information as management tool was also highlighted by workshop participants as a particularly preferable means of influencing visitor choices of site and activity and their expectations of these. Improving

Table 3—Research areas for identifying and managing recreation conflict.

Indicative information areas	Indicative research areas
Social impacts Conflict generation Crowding perceptions Coping strategies Site succession Impact tolerances Perceived differences Norm applications Site-specificity Activity-specificity Place dependence Visitor preferences Carrying capacity	* Social conflict processes. Summarize the processes of social conflict generation, emphasizing identification of characteristic patterns and notable exceptions, and including definition of any management generalizations and assumptions that can be made in different current and proposed situations. * Inter-activity conflict characteristics. Define any characteristic conflict patterns among different activity groups or different types of visitors, emphasizing any salient features of differences in motivations, appearance and behavior that most stimulate conflict perceptions. * Coping strategies. Summarize the state-of-knowledge about social impact coping strategies; their effects on visit evaluations, and any processes of recreation-experience site succession that occur. * Enhance site capacity. Identify any changes to social and physical conditions that can most enhance the capacity for different groups to share sites or to tolerate dissimilarity, and what management actions can most promote those changes. Investigate examples of successfully shared sites to identify any common factors. * Link sense-of-place to conflict perception. Investigate relationships between different sense-of-place values and the development of conflict perceptions. * Identify conflict indicators. Define the more impact-sensitive social values for sites, and derive a suite of pragmatic indicators for site monitoring based on carrying capacity standards from clearly defined site management objectives.

understanding of visitor values and of the experience outcomes from different management actions will allow better application of this information tool. As with other management options, evaluation of the effectiveness of different information strategies, and of the techniques most suited to different visitor groups and conflict issues, is important. Direct on-site approaches by credible staff will be important in some situations, while indirect use of off-site media or publication sources will be important in others. The need to have a variety of indirect and direct options to meet different management needs was highlighted.

The key question here is how can we improve the success of our management actions? Table 4 highlights the main types of research and information investigations required.

Conclusion: Integrating Research and Management

Operational managers want pragmatic guidance on how to apply any new research understandings at the site-specific level. The Department of Conservation is already establishing a site-based system for managing the facilities and services it provides for visitors. As part of this development, it planned to engage in further processes to define the physical and social conditions that should apply at these visitor sites to facilitate the social and experiential outcomes being managed for. In line with this direction, a social impact research plan is required to better define the array of social values and impacts and to integrate them with the setting of site-specific visitor management objectives.

Table 4—Research areas for evaluating management outcomes.

Indicative information areas	Indicative research areas
Management options Outcome evaluations Monitoring outcomes Quality specifications Indicators/standards Visitor satisfactions Decision processes Information options Visitor preferences	* Classify management options. Summarize the different management options for influencing on-site social and physical conditions and pre-visit visitor expectations, emphasizing social value management, and the characteristic positive and negative outcomes for different visitors associated with each option. * Evaluate management option effectiveness. Review and summarize the relative effectiveness of different direct and indirect management options, with reference to different stages in visitor planning and decision-making processes, and with emphasis on the use of information. * Evaluate visitor satisfaction applications. Summarize the effectiveness of visitor satisfaction measures in identifying social impact effects and determining the success of management interventions, and specify any limitations to the use and interpretation of such measures.. * Define “management-action” objectives. Distinguish overall site management objectives from the objectives for specific management interventions, and identify respective indicator options for management-monitoring processes. * Evaluate management systems. Summarize the state-of-knowledge on systematic recreation management frameworks and their changing strengths and weaknesses in different situations and scales of application.

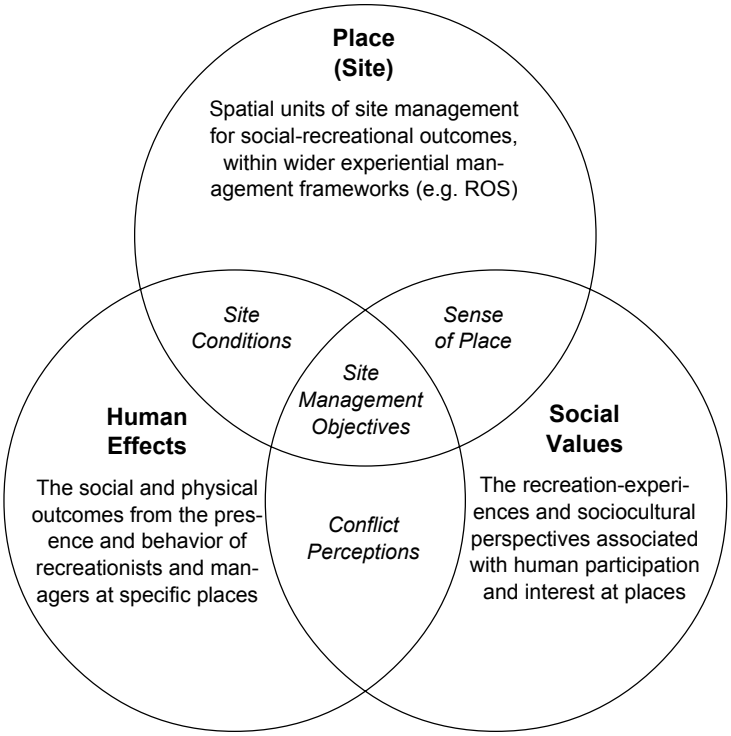

Figure 1—Interrelationships of human effects, social values and recreation places for identifying and managing social impact research needs.

The conceptual framework outlined in figure 1 summarizes how the findings from the social impact workshop can contribute to developing such a research plan. The key process at work here is the interaction between the human effects on social values at specific places. The focus of research need is clearly on improving the specification of management objectives, based on the key sociocultural and recreation-experience values at different visitor sites and the various human effects acting on them. Without these clearly specified and targeted objectives, it is unlikely that any generic monitoring methodologies will provide sufficient focus to ensure resources are effectively directed to the most pressing social impact management needs.

Research can contribute to fulfilling this need at a variety of levels. At more general levels, the investigation of different human effects and social values can increase overall knowledge and understanding. Investigations that focus on the interactions between these human effects and social values can increase understanding of how social conflict perceptions are generated, and how they might be managed. Investigations of more operational relevance to management agencies will focus on how these human effects and social values relate to managed site conditions at defined places. Managers can then use the results of such investigations to define more site-specific management objectives. Research results that promote a more site-based categorization of desired social and physical conditions, sense-of-place perspectives and conflict perceptions will be of particular value to management decision-making. Above all, the work reported in this paper highlights the need for a research framework and process that progressively incorporates different levels of research in a systematic site-based management context. Progress will be incremental as the results from different research and information sources are incorporated into any overall framework. Work to establish such a process framework should be given priority in overall research planning, leading to improved social impact management in wilderness recreation settings.

Acknowledgments

Discussion among participants at the social impact workshop provided the basis for this synthesis paper.

References

Cessford, G. R. 1999a. Social Impacts of Visitors to Conservation Lands: Part 1—Research and Information Needs. Science and Research Internal Report No. 171. Science and Research Division, Department of Conservation, Wellington, New Zealand.

Cessford, G. R. 1999b. Social Impacts of Visitors to Conservation Lands: Part 2—Workshop Proceedings. Science and Research Internal Report No. 172. Science and Research Division, Department of Conservation, Wellington, New Zealand.

Cessford, G. R. 1997. Impacts of Visitors on Natural and Historic Resources of Conservation Significance: Part 2—Research and Information Needs. Science and Research Internal Report 157. Department of Conservation, Wellington, New Zealand.

Cessford, G. R. and Dingwall, P. R. 1997. Impacts of Visitors on Natural and Historic Resources of Conservation Significance: Part 1—Workshop Proceedings. Science and Research Internal Report 156. Department of Conservation, Wellington, New Zealand.

Department of Conservation 1996. Visitor Strategy. Department of Conservation, Wellington, New Zealand.

Department of Conservation 1998. Strategic Business Plan. Department of Conservation, Wellington, New Zealand.

McCool, S. F. and Cole, D. N. (eds.) 1997. Proceedings-Limits of Acceptable Change and Related Planning Processes: Progress and Future Directions. General Technical Report INT-GTR-371. U. S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, Utah.

A Framework for Evaluating Proposals for Scientific Activities in Wilderness

Peter Landres

Abstract—This paper presents a structured framework for evaluating proposals for scientific activities in wilderness. Wilderness managers receive proposals for scientific activities ranging from unobtrusive inventorying of plants and animals to the use of chainsaws and helicopters for collecting information. Currently, there is no consistent process for evaluating proposals, resulting in confused and frustrated scientists and managers, as well as lost opportunities for gaining valuable information about a wilderness. The framework presented here is based on two premises: that both benefits and impacts are fully considered, and that communication between scientists and managers occurs at the beginning of the evaluation process.

Every year, managers in four different federal agencies receive hundreds of proposals for scientific activities to be conducted within designated wilderness. These proposals have included inventories of the plants and animals within a wilderness, marking amphibians and small mammals by toe-clipping and using radio collars on large mammals, removal of individual plants and animals for tissue analysis, and use of motorized equipment such as chainsaws or helicopters for collecting data and the installation of permanent plots and devices for recording data. Wilderness poses a unique set of opportunities and constraints on research (Butler and Roberts 1986, Franklin 1987, Greene and Franklin 1989), yet there is only vague legal and policy direction to guiding evaluation of proposed scientific activities. Each of the four wilderness agencies (USDA Forest Service, and the USDI Bureau of Land Management, National Park Service, and Fish and Wildlife Service) have their own evaluation procedures, and individual offices within an agency sometimes evaluate proposals in different ways. Further, evaluation procedures may not comprehensively consider the full range of ecological and social impacts. Inconsistent evaluation procedures leads to frustration and a lack of understanding between managers and scientists and, sometimes, the perception of arbitrary and capricious decisions in approving or denying proposals for scientific activities in wilderness.

The goal of this framework is to provide a systematic and comprehensive process for evaluating proposals to conduct scientific activities in wilderness. This framework is based largely on two premises. First, decisions to approve or deny scientific activities need to fully consider both the impacts and benefits of the proposed activity (Parsons and Graber 1991). Evaluating impacts and benefits is not an exact science, and making subjective judgments and their underlying assumptions explicit is a vital part of this framework. Second, communication between managers and scientists should occur at the beginning, rather than at the end, of the evaluation process. Improved up-front communication between managers and scientists increases the likelihood that (1) impacts from scientific activities on wilderness values will be reduced or mitigated, (2) managers will derive useful products from the proposed activities, (3) scientists will be given permission for their proposed activities, and (4) managers and scientists will have a better understanding of each others' concerns.

While no single evaluation process will work in every situation, especially in cases that have become contentious and politicized, a systematic evaluation process allows improved communication between managers and scientists and more defensible decisions.

Current Situation

Scientists and managers often fail to consider each other's context, needs and constraints. For example, scientists may not fully understand the philosophical basis of wilderness management and the impacts their activities may cause, and wilderness managers may not fully consider the potential benefits of a proposed activity to the broader system of natural areas nationwide (for example, Eichelberger and Sattler 1994). These different viewpoints, combined with the typically meager communication between scientists and managers, result in frustration and lost opportunities for both the advancement of science and wilderness protection (Peterson 1996).

Contributing to this lack of understanding and communication is inconsistency in how proposals for scientific activities are evaluated. Each of the four wilderness management agencies, and often administrative offices within these agencies, use different processes for evaluating proposals. Despite these differences, the following three screening questions, in various forms, are common to nearly all evaluation processes:

- Is the proposed activity necessary for the management of the area as wilderness?
- Is it necessary to conduct the proposed activity in wilderness?
- Will the proposed activity cause unacceptable impacts to the wilderness character?

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While these questions address valid concerns, they raise additional questions and problems. The first question is based on wording in the 1964 Wilderness Act which allows certain types of impacts if the activity is deemed "necessary to meet minimum requirements for the administration of the area for the purpose of this Act." However, the Wilderness Act does not define what these "minimum requirements" are or under what set of conditions they apply, leading to different interpretations by different people and different agencies.

The second question is largely based on the assumption that scientific activities are an intrusion and sometimes a threat to wilderness character, and if the activity could be conducted outside the wilderness, it should be. While it is a valid consideration, exclusive emphasis on minimizing impacts may restrict scientific activities unduly, leading to a lack of information about wilderness conditions and, possibly, adversarial relations between managers and scientists. These poor relationships may further stem the development of new and better information needed to protect wilderness and to plan for its future.

The last question poses the most difficult problem since all human activities cause impacts to wilderness, yet acceptability of the impact varies from one activity to another and from one situation to the next, often with little consistency or adequate definition. Acceptability can also change over time. For example, relatively pristine wilderness conditions are increasingly unique, and scientists believe ecological and social science activities within wilderness are of increasingly greater value beyond the boundaries of the wilderness. Many managers, however, are unwilling to accept impacts to an individual wilderness from scientific activities that provide only broad-scale, and more loosely defined, societal benefits.

Evaluation Framework

This framework is composed of three sequential filters: a Legal and Policy Filter, a Benefits and Impacts Filter and a Quality of Design Filter (fig. 1). The first filter helps determine if the proposed activity fits within the "minimum requirements" provision of the Wilderness Act and is compatible with other applicable legal, policy and planning documents for that wilderness. If the activity passes this filter, the second filter, composed of two stages, evaluates the relative benefits and impacts of the proposed activity. The first stage is a rapid assessment of benefits and impacts that classifies the proposed activity "approved to next filter," "denied" or "further evaluation needed." For proposed activities falling into the last class, the second stage is a comprehensive and in-depth evaluation of what the benefits of the activity are, who derives this benefit, what the ecological and social impacts are and whether these impacts can be prevented, minimized or mitigated. The third filter and last step in this process is to evaluate if the proposed activity is well-designed and capable of providing its intended outcome.

This framework includes all the elements that are necessary and sufficient to evaluate a proposed scientific activity. In some cases, this process will lead to quick decisions, while in other cases, the process will identify the need for

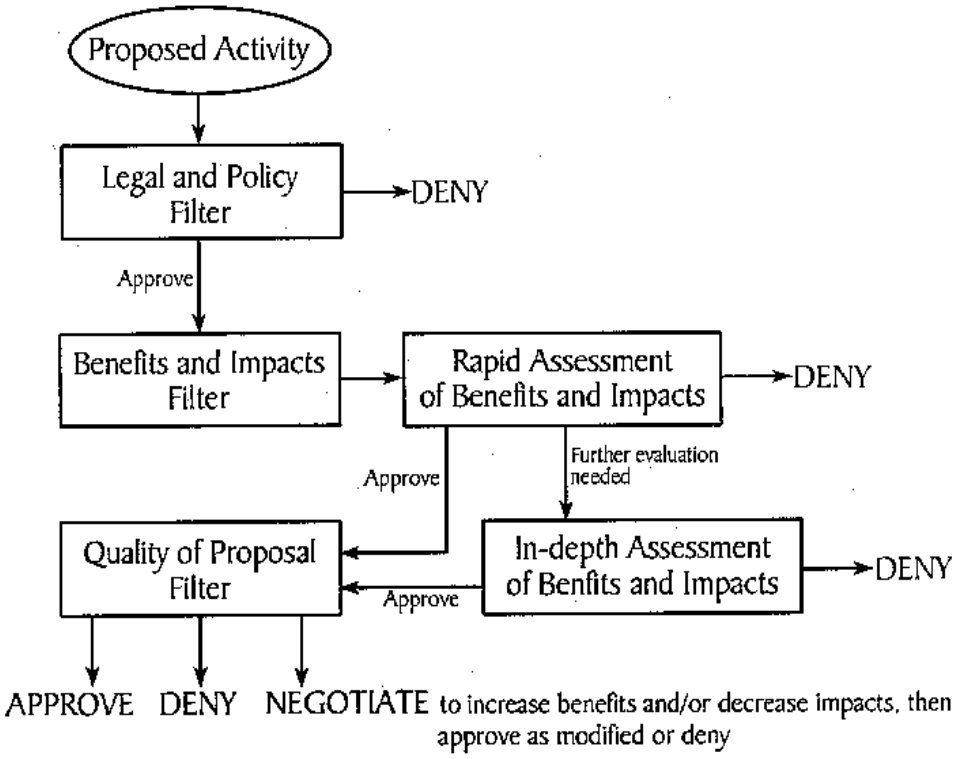

Figure 1—A systematic framework for evaluating proposals for scientific activities in wilderness.

a comprehensive evaluation that will take longer and be much more difficult. Subjective judgments are an integral part of evaluating proposed activities in many cases, especially in those needing a comprehensive evaluation of benefits and impacts. The proposed framework makes these judgments and their underlying assumptions more explicit, and allows their merits and limitations to be openly discussed. In addition, if a structured process is used to evaluate proposals, scientists and managers can discuss how the proposal will be evaluated *before* it is submitted. If scientists understand this process and that both benefits and impacts of their proposed activity will be rigorously evaluated, they will strive to minimize the impacts and maximize the benefits of their work. This structured process provides a sound basis for improved communication between managers and scientists, leading to scientific activities that may be tailored to maximize their benefits to wilderness and wilderness managers.

Legal and Policy Filter

Scientific activities that violate applicable laws and agency policies are not allowed in wilderness. In addition, most managers strive to fulfill the spirit of the Wilderness Act as well as the letter of the law. In some cases, however, the spirit of the law is obscured by ambiguous wording in both legislation and agency policy. For example, Section 4(c) of the Wilderness Act of 1964, "Prohibition of Certain Uses," reads in full:

> Except as specifically provided for in this Act, and subject to existing private rights, there shall be no commercial enterprise and no permanent road within any wilderness area designated by this Act and, *except as necessary to meet minimum requirements for the administration of the area for the purpose of this Act* (including measures required in emergencies involving the health and safety of persons within the area), there shall be no temporary road, no use of motor vehicles, motorized equipment or motorboats, no landing of aircraft, no other form of mechanical transport, and no structure or installation within any such area. [emphasis added]

In other words, *if* a proposed activity is "necessary" for the "minimum requirements for the administration of the area," *then* the typical prohibitions may be relaxed. The problem is that "necessary" and "minimum requirement" are nowhere defined in the Wilderness Act or in other wilderness legislation, leading to different definitions and criteria used by different people in different situations. Additional confusion is caused when different people interpret the phrase "for the purpose of this Act." Some consider the "purpose" of the Wilderness Act to protect and preserve wilderness for the enjoyment of present and future generations, which is primarily a recreation focus. Others consider this "purpose" to be much broader, to secure "the benefits of an enduring resource of wilderness," and these benefits are "recreational, scenic, scientific, educational, conservation, and historical use" (Sections 2(a) and 4(b), respectively, of the Wilderness Act of 1964). The broader view typically considers scientific activities to be an integral part of wilderness.

To help resolve these problems, the USDA Forest Service is developing guidelines for determining whether a proposed activity is the minimum required for administration of an area as wilderness. The Legal and Policy Filter shown in figure 2 is modified from the Forest Service's draft "Minimum Requirement Determination Guide" for the specific case of scientific activities. In this filter, the first three questions are used to determine if an activity must be approved. However, even if an activity is approved via any of these first three questions, negotiation may still be used to reduce and mitigate impacts. Proposed activities that pass to the fourth question require further evaluation based on eight additional questions that yield subjective "yes/no" answers. After these questions are answered, an individual determination is made about denying the activities because they fail to meet legal and policy standards, or approving them to be evaluated in the remaining two filters.

Benefits and Impacts Filter

If a proposed activity passes through the Legal and Policy Filter, the potential benefits and impacts of the activity are evaluated. Most of the processes currently used to evaluate proposals for scientific activities, especially within the Forest Service, largely focus on potential impacts and either ignore or underrate potential benefits. Focusing on impacts stems from the traditional view that scientific activities are primarily an intrusion in wilderness. This traditional view should be evaluated against the view that wilderness offers a unique opportunity to learn about the structure and functioning of both ecological and social systems in relatively pristine environments, and that this information may be of great value to wilderness managers, natural resource agencies and society at large.

This filter is composed of two stages. The first is a rapid assessment of benefits and impacts, yielding a quick decision about whether the proposed activity is denied, approved or further evaluation of impacts and benefits is needed. The second stage is an indepth evaluation of benefits and impacts. To understand how this filter and these two stages work, a brief description of benefits and impacts follows.

Benefits depend on who considers the information important and how it might eventually be used. In addition, these benefits may extend well beyond the boundary of the protected area. There are three relatively distinct groups that may derive benefits from proposed activities: (1) wilderness managers gaining information about the wilderness they manage; (2) regional and national-level managers and policymakers gaining information about several wildernesses or the entire National Wilderness Preservation System; and (3) society at large gaining information about relatively pristine ecological systems and the benefits people derive from these. Each of these users typically operates at a different spatial and temporal scale, and proposed activities are typically designed for one scale and therefore typically benefit one user more than another (fig. 3). For example, site-specific activities may provide knowledge about the flora or threatened and endangered species in one wilderness, but this information is of less importance to other wildernesses. Conversely, some activities, such as the Forest Health Monitoring program, are designed to collect a small amount of information from many wildernesses that, when summarized, provides critical information for national-level assessments.

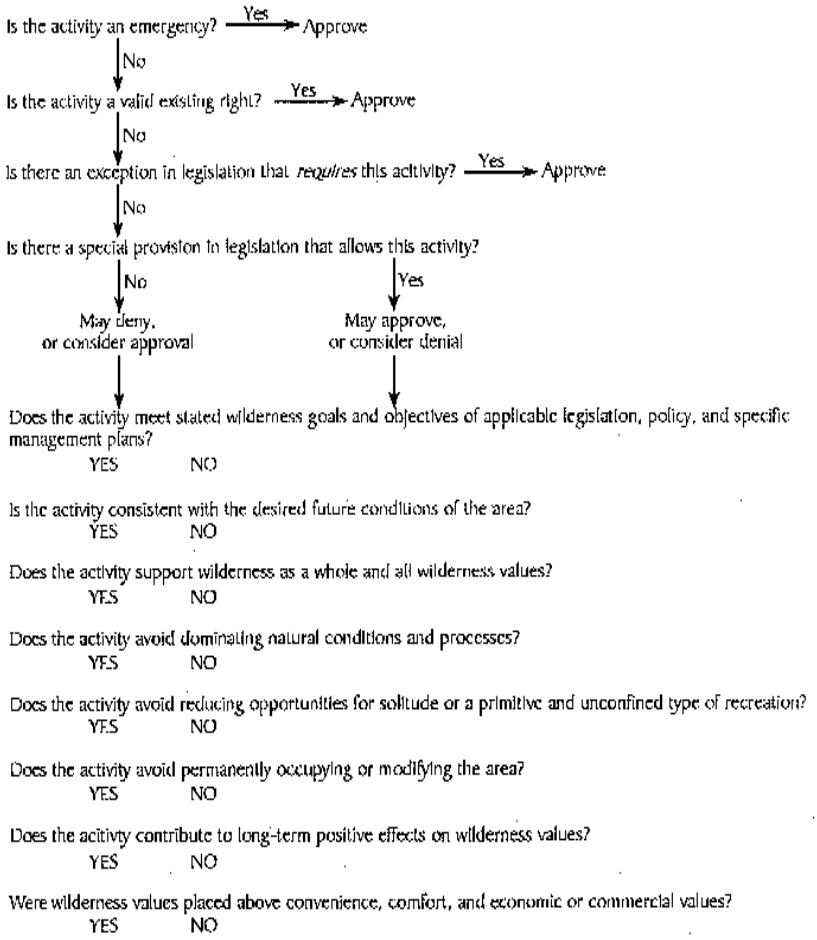

Figure 2—The Legal and Policy Filter. This filter is modified from the draft "Minimum Requirement Determination Guide" developed by the USDA Forest Service, 1999, used by permission. The first three questions yield direct "yes/no" answers that are used to determine if an activity must be approved. Even if an activity is approved via one of these three questions, negotiation may still be used to reduce and mitigate impacts. The fourth question about special provisions, and the remaining eight questions, yield subjective "yes/no" answers: a greater number of "yes" answers suggests approval of the activity while a greater number of "no" answers suggests denying the activity.

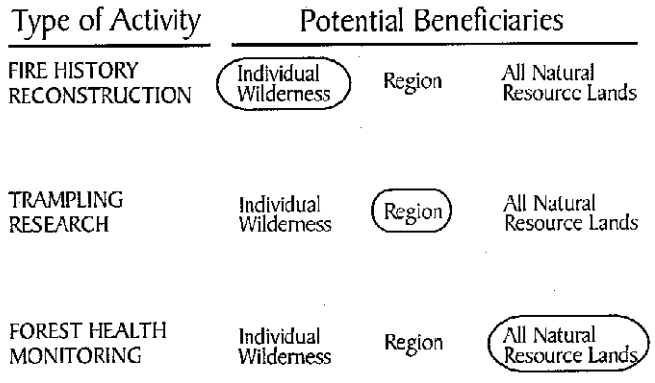

Figure 3—Diagrammatic view of the primary beneficiary (circled) of different types of scientific activities. While any given activity may benefit all of these different levels, an activity is usually designed to provide information primarily about one level, resulting in relatively greater benefits to this level.

Impacts may occur to both the ecological and social values of wilderness. Ecological impacts may include trampling plants, collecting specimens, disturbing soil, trapping and marking animals which are then released, or the use of exclosures or inclosures. Social impacts may include an increased number of encounters with scientists and their field crews, the sound and sight of motorized equipment or visual impacts from tags, markers and other equipment that affect a primitive wilderness experience. Social impacts also include philosophical concerns about a proposed activity that may, for example, set a precedent for violating the untrammeled character of a wilderness. For example, to some people, using helicopters to access remote locations for lake or vegetation monitoring, or for placing radio collars on threatened and endangered species such as wolverines, is a clear violation of the spirit and letter of the Wilderness Act.

Fundamental questions asked about all impacts include: (1) How big an area will be affected? (2) How intense will the impact(s) be? (3) How long will the impact(s) last? (4) Can the

impact(s) be mitigated, both during the activity and after it is completed? In many, if not most cases, there will be no precise or hard information on impacts. Relying on subjective judgment is appropriate in such cases as long as these judgments and underlying assumptions are made explicit so their merits and detriments can be openly discussed and debated.

The first, rapid assessment stage of benefits and impacts is based on a simple two-way "benefits-impacts matrix" (fig. 4). The purpose of this matrix is to rapidly identify and approve proposed activities that provide large benefits with little impact and identify and deny those activities that offer little or no benefit but cause considerable impacts. Also, it is suggested that proposed activities which offer few or no direct benefits and cause little impact be readily approved (Graber 1988). Some may argue that the latter should be denied because they do not fulfill the necessary minimum requirements discussed earlier and that all unnecessary activities further trammel an area. In contrast, these activities are relatively benign, they may provide baseline information with unanticipated later usefulness, and they may fit under the "recreational, scenic, scientific, educational, conservation, and historical" uses described in the Wilderness Act of 1964.

The second, indepth evaluation stage is required because relatively few proposed activities will be readily approved or denied in the first, rapid assessment stage. Instead, many proposed activities will likely require indepth evaluation of the tradeoffs between potential benefits and impacts. Evaluating tradeoffs is as much art as science, and several different approaches may be taken. The approach described here first evaluates impacts in greater detail; these impacts are then compared to the benefits of the proposed activity. There are no objective, quantitative means for making this evaluation, and once the benefits and impacts are explicit, the decision-maker will need to make a subjective judgment about whether the benefits of the proposed activity outweigh the impacts, or vice versa.

Each proposed activity will probably have many different types of impacts, and it is crucial that all impacts are listed so they can be evaluated. A comprehensive evaluation needs to consider three broad types of impacts:

- Biophysical — impact to plants, animals, soil or ecological processes
- Recreational — impacts to solitude or opportunities for primitive recreation experiences
- Societal — impacts to the social purposes for which wilderness was created, including impacts to wildness or the untrammeled character of wilderness and the precedent an activity sets for wilderness nationwide

One way to evaluate impacts in greater detail is to array the amount of area affected against the intensity of the impact in a two-way "impacts matrix" and assign numerical categories to the different levels of overall impact (fig. 5). Specific data will usually not be available to evaluate an impact in this manner, so judgments are appropriate as long as the assumptions and constraints behind a judgment are made explicit. Each potential impact and its numerical score can then be listed together to provide a picture of the impacts from a proposed activity (figs. 6, 7 and 8). Listing all the potential biophysical, recreational, and societal impacts in this way should make apparent the specific impacts that are of greatest concern, allowing explicit discussions about accepting these impacts or how to minimize or mitigate them.

Quality of Design Filter

The outcome from the indepth evaluation of benefits and impacts is to either deny the proposed activity or to approve it to the last Quality of Design Filter. The purpose of this last filter is to ensure that the proposed work is adequately designed to meet its intended goals and objectives. It may be the most challenging for managers if they are not trained in scientific methods of research design, sampling theory and statistical analysis. Managers have four options to assess the quality of the proposed activity: (1) Review the design

BENEFITS

IMPACTS	Few	Some	Many
Few	Approve	Approve	Approve
Some	??	??	Approve
Many	Deny	Deny	??

Figure 4—A *benefits-impacts matrix* used to rapidly assess proposed activities into one of three categories: "Approve" to the next Quality of Design Filter, "Deny," or proceed to an in-depth evaluation (denoted by "??"). The assignments shown here are merely to illustrate the process. The office or person doing this evaluation must develop their own assignment of "Approve," "Deny," and "??" into each box of this matrix.

SIZE OF IMPACTED AREA

INTENSITY OF IMPACT	Small	Medium	Large
Small	1	2	3
Medium	2	3	4
High	3	4	5

Figure 5—An *in-depth impacts matrix* used in the evaluation of impacts by assigning numerical categories of overall impact. The numbers used here merely illustrate the process. The office or person doing this evaluation must develop their own assignment of numerical ratings into each box of this matrix.

TYPE OF IMPACT	AMOUNT OF IMPACT				
BIOPHYSICAL IMPACTS					
Sawcuts in living trees (small area, high intensity)	1	2	(3)	4	5
Trampling of vegetation (medium area, weak intensity)	1	(2)	3	4	5
Noise displacement of wildlife (medium area, medium intensity)	1	2	(3)	4	5
RECREATIONAL IMPACTS					
Sight of sawcut stumps (small area, high intensity)	1	2	(3)	4	5
Sight of chainsaws (small area, high intensity)	1	2	(3)	4	5
Noise of chainsaws (medium area, high intensity)	1	2	3	(4)	5
Encounters with field crews (medium area, weak intensity)	1	(2)	3	4	5
SOCIETAL IMPACTS					
Precendent of using chainsaws (large area, high intensity)	1	2	3	4	(5)

Figure 6—Example of an in-depth evaluation of the impacts from proposed *fire history reconstruction research* in a wilderness. This example is not exhaustive and only shows representative impacts within each of the three broad types of impacts. Parenthetical statements below each impact represent judgments of the amount of area affected and the intensity of impact. The circled numbers shown here reflect these judgments of impact based on the numerical categories shown in the in-depth impacts matrix (fig. 5). The judgments of impacts and numerical ratings shown here are only representative and do not reflect actual ratings.

TYPE OF IMPACT	AMOUNT OF IMPACT				
BIOPHYSICAL IMPACTS					
Trampling of vegetation (small area, high intensity)	1	2	(3)	4	5
Soil erosion (small area, high intensity)	1	2	(3)	4	5
RECREATIONAL IMPACTS					
Sight of trampling plots (small area, high intensity)	1	2	(3)	4	5
Encounters with field crews (medium area, weak intensity)	1	(2)	3	4	5
SOCIETAL IMPACTS					
Precendent of purposeful trampling (large area, high intensity)	1	2	3	4	(5)

Figure 7—Example of an in-depth evaluation of the impacts from proposed *trampling research* in a wilderness. This example is not exhaustive and only shows representative impacts within each of the three broad types of impacts. Parenthetical statements below each impact represent judgments of the amount of area affected and the intensity of impact. The circled numbers shown here reflect these judgments of impact based on the numerical categories shown in the in-depth impacts matrix (fig. 5). The judgments of impacts and numerical ratings shown here are only representative and do not reflect actual ratings.

TYPE OF IMPACT	AMOUNT OF IMPACT				
BIOPHYSICAL IMPACTS					
Trampling of vegetation (small area, weak intensity)	(1)	2	3	4	5
Driving nails in trees (small area, weak intensity)	(1)	2	3	4	5
RECREATIONAL IMPACTS					
Sight of permanent plot markers (small area, medium intensity)	1	(2)	3	4	5
Encounters with field crews (medium area, weak intensity)	1	(2)	3	4	5
SOCIETAL IMPACTS					
Precendent of national-level monitoring in wilderness (large area, medium intensity)	1	2	3	(4)	5

Figure 8—Example of an in-depth evaluation of the impacts from proposed *forest health monitoring* in a wilderness. This example is not exhaustive and only shows representative impacts within each of the three broad types of impacts. Parenthetical statements below each impact represent judgments of the amount of area affected and the intensity of impact. The circled numbers shown here reflect these judgments of impact based on the numerical categories shown in the in-depth impacts matrix (fig. 5). The judgments of impacts and numerical ratings shown here are only representative and do not reflect actual ratings.

quality of the proposal themselves; (2) ask their in-house science staff to review the proposal; (3) ask outside scientists for review; or (4) assume that the proposal is sufficiently well-designed that no review is needed. The drawbacks to the first three options are the staff time and funding needed to review proposals. While the fourth option may appear specious, some national-level cases such as the Forest Health Monitoring program are developed with rigorous standards and don't need to be reviewed for design quality.

The outcome from this Quality of Design Filter is to deny the proposed activity, approve it or negotiate with the proposer about how to maximize the benefits and how to reduce or mitigate impacts from the proposed activity.

Conclusions

This framework provides a process for systematically and comprehensively evaluating the benefits and impacts of proposals for scientific activities in wilderness. Fully considering the benefits and impacts of a proposed activity, and making all judgments and assumptions explicit, allows informed and defensible decisions. Furthermore, a systematic and comprehensive framework provides the basis for consistent and explicit communication between managers and scientists. Despite these advantages, this framework cannot be used "off-the-shelf." The managers of each wilderness will need to tailor and modify it to suite their particular administrative and philosophical context and constraints. This framework also points to the critical need for agencies to publish formal guidelines describing exactly how proposals for scientific activities will be evaluated.

Such guidelines provide the basis for explicit, up-front discussions between managers and scientists, leading to scientific activities tailored to reduce their impacts and increase their benefits to wilderness and wilderness managers.

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The development of this framework has greatly benefitted from discussions with many scientists and managers, especially Dave Graber, Bob Krumenaker, Linda Merigliano, Dave Parsons, Rick Potts, Chris Ryan, Tom Swetnam, Keith Waterfall and Jim Walters. I'm especially grateful to the hard work of Chris Ryan and Dan Ritter for developing, and allowing me to use, the "Minimum Requirement Determination Guide" as the legal and policy filter in this evaluation framework. The editorial comments of Jennifer O'Loughlin are greatly appreciated.

References

Butler, L.M., and R.S. Roberts. 1986. Use of wilderness areas for research. Pages 398-405 *in* Proceedings — National Wilderness Research Conference: Current Research (R.C. Lucas, compiler). USDA Forest Service General Technical Report INT-212, Intermountain Research Station, Ogden, UT.

Eichelberger, J., and A. Sattler. 1994. Conflict of values necessitates public lands research policy. Transactions of the American Geophysical Union 75:505-508.

Franklin, J.F. 1987. Scientific use of wilderness. Pages 42-46 *in* Proceedings — National Wilderness Research Conference: Issues, State-of-Knowledge, Future Directions (R.C. Lucas, compiler). USDA Forest Service General Technical Report INT-220, Intermountain Research Station, Ogden, UT.

Graber, D.M. 1988. The role of research in wilderness. George Wright FORUM 5:55-59.

Greene, S.E., and J.F. Franklin. 1989. The state of ecological research in Forest Service wilderness. Pages 113-119 *in* Wilderness Benchmark 1988: Proceedings of the National Wilderness Colloquium (H.R. Freilich, compiler). USDA Forest Service General Technical Report SE-51, Southeastern Forest and Experiment Station, Asheville, NC.

Parsons, D.J., and D.M. Graber. 1991. Horses, helicopters and hi-tech: managing science in wilderness. Pages 90-94 *in* Preparing to Manage Wilderness in the 21st Century (P.C. Reed, compiler). USDA Forest Service General Technical Report SE-66, Southeastern Forest and Experiment Station, Asheville, NC.

Peterson, D.L. 1996. Research in parks and protected areas: forging the link between science and management. Pages 417-434 *in* National Parks and Protected Areas: Their Role in Environmental Protection (R.G. Wright, J. Lemmons, editors). Blackwell Science.

Wolf Research in the Isle Royale Wilderness: Do the Ends Justify the Means?

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AbstractóIsle Royale National Park is a remote island ecosystem in Lake Superior. A long-term research program investigating the wolf and moose populations in the Park has provided the public and scientific community with valuable information on the ecology of these species in this wilderness setting. A persistent decline within the wolf population led to a change in the direction of the research program and research methods used, leading to concerns about the impacts of the research efforts to the wilderness values in the Park. An expert panel review was used to review the issue and provide recommendations to Park management.

Isle Royale National Park is a wilderness archipelago in northwest Lake Superior, consisting of one large island surrounded by hundreds of smaller islands (fig. 1). The Park (or ìislandî) contains 224,500 ha, a mix of Lake Superior waters and a 52,400 ha land base. Much of the island wilderness lies under a mantle of boreal and northern hardwood forest. Due to the Parkís isolation, a distance of 24 km at the closest point across the cold waters of Lake Superior to Ontario or Minnesota, species numbers are significantly less than on the mainland. The Park has long been recognized as an outstanding natural laboratory because of this relatively simplified ecosystem and, in 1980, was designated as a U.S. Biosphere Reserve under the United Nations Man and the Biosphere Programme.

Approximately 98% of the land base was designated as wilderness in 1976 and later expanded to include 99% of the land base. Visitors come to the Park expecting to achieve a quality wilderness experience. Significant features of the Park wilderness include the gray wolf (*Canis lupus*) and moose (*Alces alces*) populations, which are the focus of a long-term research program that has provided over four decades of data for this predator-prey system. As changes have occurred within this system and research techniques have advanced, however, concerns have arisen over the appropriateness of the type of research being conducted within the Park wilderness, particularly in terms of the need to handle wolves.

The potential impact of the research methods on the wilderness values has confronted Park management for over a decade. The Park chose to seek the recommendations of an external, expert review panel to help resolve the issue of the appropriateness of the research program within the park wilderness. This paper summarizes the issues in the debate and the use of the expert review panel to address the issues.

Historical Context

Although wolves and moose are the dominant carnivore and herbivore in the terrestrial island ecosystem, there is no archeological evidence that either species was present prior to the 20th century (Clark 1995). Moose arrived at Isle Royale by approximately 1915, and ultimately replaced the caribou (*Rangifer tarandus*); the gray wolf arrived in the winter of 1948–1949, and eventually eliminated the coyote (*Canis latrans)* (Mech 1966*)*.

Wolf and Moose Populations on the Island

For the 35–40 years that moose were present on the island without a predator, at least one major population crash occurred in the moose population (1934), the result of severe overbrowsing of the limited food supply (Mech 1966). The

Figure 1—Isle Royale National Park, Michigan.

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gray wolf arrived in 1948 and inserted some influence over the moose population (Mech 1966; Peterson 1977). Both populations have varied dramatically since research began in 1958 (fig. 2). Moose population estimates during 1959-1988 were based on population reconstruction from recoveries of dead moose, whereas estimates from 1989-1999 are based on aerial surveys (Peterson and Page 1988; Peterson 1999a). Wolf population counts are total counts from aerial surveys.

The wolf population crashed from 50 to 14 animals between 1980 and 1982, which led to a major change in the dynamics of this predator-prey system. Low wolf numbers well into the 1990s allowed the moose population to grow significantly. This wolf crash also led to a change in the methods and direction of the research program, from a "hands-off" approach to one requiring the handling of animals. The handling of wolves generated information that in turn added new priorities to the type of information collected in the research program, by emphasizing the importance of genetic information. By the early 1990s, wolf extinction became accepted as a likely outcome, because of the highly inbred nature of the population and failure of the population to increase despite an apparently adequate food supply. However, increased pup production in the mid-1990s nudged the population into the mid-20s, comparable to its long-term average. The population stood at 25 animals by March 1999 (Peterson 1999a).

The moose population has experienced equally dramatic swings since the research program began, with a major crash during the severe winter of 1996. The population dropped from 2,500 to 500 animals then, largely due to a combination of starvation and parasites (Peterson 1999b). Since then the population has begun to slowly rebound and stood at 750 animals by March 1999.

Wolf Research Program on the Island

The formal wolf research program began in 1958 (Allen 1979; Mech 1966) and has continued with the aim of determining annual population numbers for both wolves and moose (Jordan and others 1967; Mech 1966; Peterson 1977; Peterson and Page 1988). A primary long-term objective has been to understand population regulation for wolves and moose in this insular ecosystem isolated from human-caused mortality. With the exception of a nonnative virus introduction into the wolf population around 1980, both populations have been free of virtually all direct human impacts (hunting, human-induced habitat changes, road/vehicle impacts). Since the research program began, all monitoring activities were done remotely, from aerial observation. No handling of the wolves was permitted because of the perceived wilderness value placed on maintaining an "untouched" wolf population. In the late 1980s, the value of the wolf population for gaining insights in conservation biology was heightened as the population dropped to 12 and remained low for several years.

The wolf population crash of 1980-82 and subsequent failure to rebound created concern about the future of the Park's wolf population. In 1988, at the request of the National Park Service (NPS), researchers initiated handling and radio-collaring of wolves in the Park for the first time, in order to determine individual causes of mortality. The findings added interest in the effects of disease and genetics on wolf population dynamics. The studies documented introduced disease (canine parvovirus) on the island during the 1980s, and the wolves were found to be highly inbred descendants of a single maternal ancestor (Wayne and others 1991; Lehman and others 1991; Peterson and others 1998).

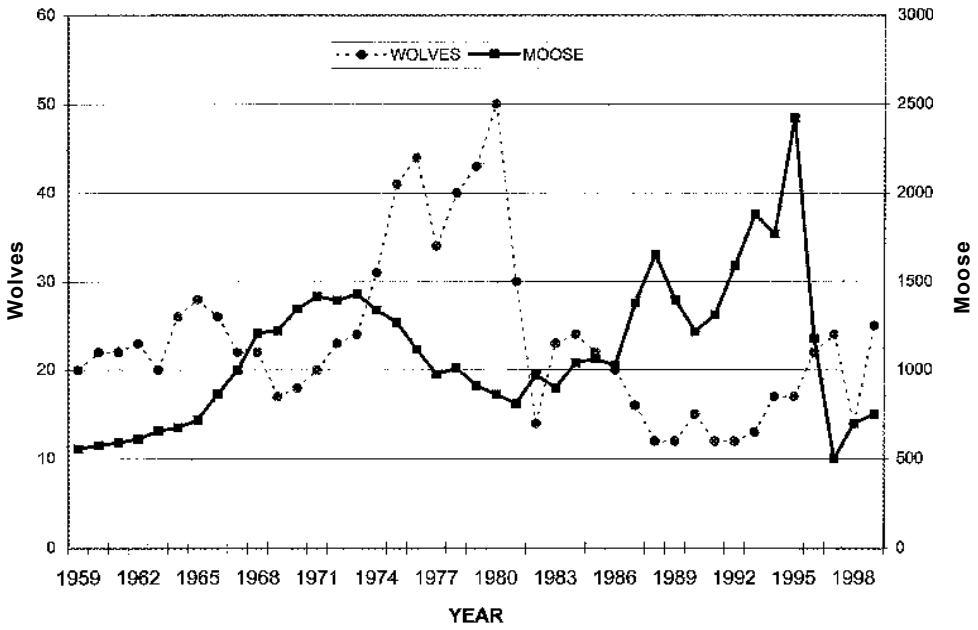

Figure 2—Wolf and moose populations, Isle Royale National Park, 1959–1999.

During 1988–1999, as many as six wolves were radio-collared at a single time, while the population fluctuated from 12 to 25. Seventeen wolves were handled and radio-collared from 1988–1999. Live-capture efforts were aimed initially (1988–1992) at as high a proportion of the population as possible (10 of the 12 wolves present in 1988 were live-captured for study). During 1993–1998, capture efforts were reduced to target no more than two wolves in each of the three packs on the island during this time.

Values Associated With the Wolf Research Program

The NPS recognizes several positive outcomes of the long-term wolf research program. Park management has made several substantive decisions based on the research findings and needs, including: 1) a complete Park closure to visitor use from November 1–April 14 of each year, largely to facilitate the research program and prevent harassment of the wildlife during winter recreational activity, 2) prohibition of overnight camping in approximately 50% of the Park to protect wolf denning sites and to keep visitors from coming into close contact with wolf pups, thus preventing habituation to humans, and 3) a prohibition of mammalian pets on the island to reduce disease introductions.

Other recognized values of the research program have included the wide dissemination of natural history information on the wolf and moose populations of the Park, particularly as it has described these populations in an environment free of human harassment and interference. An adoring global public now awaits the annual updates of these populations. Some information indicates that visitor sightings of wolves in the Park have increased in the last 30 years as research information has been communicated to the public (Vucetich and Vucetich 1999, unpublished data), perhaps the result of a public much more aware of these animals due to the research efforts.

Similarly, the long-term monitoring data have complemented the NPS mission of long-term protection of the Park resources by providing status and trends. Finally, 30 years of population data provided a compelling argument that significant change had occurred, and when wolf numbers dropped so low in the late 1980s more intensive investigation was warranted. This database enabled Park management and the research community to assess the need for intensive handling of the wolf population.

The Park recently completed a General Management Plan (USDI 1999), a planning effort to focus management direction for the next 15 to 20 years. That process included the identification of Park Significance statements (which describe the Park's *distinctiveness* on a national and international scale), and Park Purpose statements (which describe *why* Isle Royale was set aside as a national park). One of three Significance statements included the statement that "Isle Royale is world renowned for it's long-term wolf/moose predator/prey study. The park offers outstanding possibilities for research in a remote, relatively simple ecosystem where overt human influences are limited." One of five Park Purpose statements states the Park will "provide opportunities for scientific study of ecosystem components and processes, including human influences and use, and share the findings with the public."

Description of Study Area

Wilderness Values of the Park

The remote location and difficulty in accessing the island has protected Isle Royale from excessive development and recreational use. Park visitation in the 1990s ranged from 15,000 to 18,500 annually. Many of the recognized values of wilderness—opportunities for solitude, unconfined recreation, a landscape largely devoid of the human imprint—are found at Isle Royale. Recreational activities associated with wilderness, including backpacking, kayaking and canoeing, represent the largest user groups of the Park.

In the 1931 Senate report that recommended Isle Royale for national park status, NPS Director Horace Albright described Isle Royale as having "the appearance of being almost entirely in its primeval state," and later referenced the "wilderness character of the park." Noted wildlife biologist Adolph Murie, who spent time in the Park in the late 1920s studying the moose population, wrote of the need to minimize development within the new Park to protect its wild character, even to the point of recommending no trail development to avoid damaging the wilderness character of the island (Murie 1935). Park management ultimately ignored his recommendations in response to growing visitation, and today 165 miles of trail cross the island.

Isle Royale represents a wilderness landscape unique in North America. It is a landscape with no adjacent terrestrial land boundaries and thus avoids the conflicts of neighboring lands management practices, political considerations or immigration/emigration of wildlife, which often heightens the need for management of the wildlife resources. This isolation is a critically important distinction for this Park and its wildlife populations. It allows for consideration of a "hands-off" approach to wildlife management, wherein manipulation or intervention—even to the point of strictly non-intrusive research and observation—should be minimized to the greatest extent possible, based on concerns for wilderness values. It allows for consideration of protecting the wildlife populations to keep them completely untouched by humans, as a baseline of *wilderness* wildlife management at one end of the wildlife management spectrum.

Related to wilderness, the park's General Management Plan included one Park Purpose statement stating the need to "preserve and protect the park's wilderness character for use and enjoyment by present and future generations," and one Park Significance statement stating "this maritime park, a US biosphere, encompasses a remote and primitive wilderness archipelago isolated by the size and power of Lake Superior."

Clearly, from the early days of the Park through the present intensive planning activities by the NPS, "wilderness" has remained the unifying theme that captures the essence of these remote islands.

Potential Conflicts Between the Wolf Research Program and Wilderness Values of the Park

The decision to handle wolves for the first time in Park history in 1988 was a difficult one for the NPS. Advice was sought both internally within the NPS and from the research community. Besides being responsive to the "minimum tool" requirements for research actions within wilderness, both researchers and the Park recognized the near-mythical status of this population, due to its existence completely free from human harassment. As early as the 1960s popular magazine articles recounted the wolf and moose story on this "remote wilderness island" (Allen and Mech 1963). But as the wolf population decline persisted in the late 1980s, a peer-reviewed proposal in 1988 recommended the need to handle wolves on the island to assess the persistent wolf population decline and high mortality rate. The practice of handling wolves continued following a meeting of specialists that reviewed the first-year findings. During that period, no "end-date" for how long the handling was to continue was discussed; rather, most experts involved believed that answers to the questions of the wolf decline would be gained quickly and resolve the issue. Disease as a major factor in the Isle Royale wolf decline was eventually implicated in the persistent decline (Peterson and others 1998).

However, results of genetics and disease testing of these handled wolves led to a much broader understanding of issues related to wild canid populations. Indeed, it is now recognized that the wolves of Isle Royale provide an unprecedented opportunity to determine the significance of genetic losses for long-term viability in small, isolated populations, one of the major tenets of conservation biology.

As wolf handling continued, the need to consider the "minimum tool" requirement for the wolf research project, in terms of whether to continue to handle wolves or revert to strictly "hands-off" monitoring, continued to confront Park management in the 1990s. This debate is rooted in the wilderness management policies of the NPS (USDI 1988) and the NPS tradition of a "hands-off" wildlife management approach (Peterson 1999b). Concerns have been often voiced by NPS employees involved in wilderness management at Isle Royale and other wilderness areas, but also by wilderness philosophers (Turner 1997).

Methods

As the value of the research information increased, particularly in terms of tracking the genetic decay of this highly inbred population, it was suggested that an independent scientific panel be convened to assess the issue and recommend a course of action to the NPS. It was felt an outside panel could provide an objective and scientifically valid opinion on the merits of continued handling. The scientific review followed the suggestions outlined by Meffe and other (1998). The panel convened in April 1999, and consisted of three experts (two from the USGS Biological Resources Division, one from the Aldo Leopold Wilderness Research Institute), with participation from NPS employees and the principal investigator for the wolf research project (Dr. Rolf Peterson). Panel members were selected based on expertise in wolf research and wildlife management and/or familiarity with wilderness and wildlife management in the NPS.

The expert review panel was asked to review pertinent information on the Isle Royale wolf population and the wilderness values associated with the Park and provide a recommendation to Park management on the following issues:

> Given the past and current wolf population status in the park, anticipated future research needs, and the wilderness designation of the park, is it necessary to continue to livetrap and handle wolves on the Island? Or can the research/monitoring program return back to a "non-handling" monitoring? Have we answered the important questions through the handling of wolves over the past 10 years?

Results

Discussion Summary From the Expert Panel Review

The panel reviewed the relevant issue information and identified the advantages of handling wolves and of not handling wolves as a means to determine a recommendation. That information, with a recommendation, was submitted to Park management in a summary report (Isle Royale National Park 1999a), and is summarized as:

Gains of Handling Wolves—

- Handling wolves maintains the ability to monitor the genetic deterioration that may result from small population size and absence of immigration. Because the Isle Royale wolves are the smallest, most isolated population in the world (with the possible exception of a small Swedish population), they may be more prone to inbreeding depression and elevated extinction risk. Contrary to conventional belief in biological science that such populations will not persist, the Isle Royale wolf population has persisted for 50 years and thus provides a very valuable scientific experiment.
- Research information provides a higher quality level of natural history interpretation for visitors. There is significant public value to the island wolf/moose story.
- Handling wolves maintains the ability to test other research techniques for identifying individuals within the population (for example, using wolf scat DNA to identify individuals within the population, which has global applications for other isolated populations).
- Also maintained is the ability to track diseases in the population, including the types, effects, vectors and course of diseases; the relationship of disease to survival; and the detection of diseases and explanation of the effects.
- The ability to monitor survival and causes of wolf mortality (collaring is needed to locate dead wolves) is maintained, although such monitoring is limited by the small number of collared wolves and the ability to look for and study dead wolves only during certain seasons of the year.

Gains of Not Handling Wolves—

- Not handling wolves would contribute to maintaining the Park as pristine. This approach would preserve the mystique of wilderness and the "resource of wilderness" condition "untrammeled" by man called for in the Wilderness Act of 1964 (Public Law 88-577). As an isolated island, Isle Royale provides one of the best opportunities for an untouched wildlife population and contributes to a fuller continuum of wilderness conditions, particularly in terms of wildlife management in wilderness.
- The potential to avoid potential human-caused injury to animals from the livetrapping of wolves through modified leg-hold traps is removed.
- The potential to avoid potential alteration of wildlife behavior through the stress of handling is similarly removed, although there is no scientific evidence of such impacts on behavior.
- This approach preserves the possible scientific value of maintaining baseline conditions for an untouched population. This value is not identified currently, but not handling wolves now would preserve future options if such value is identified. The effects of handling would probably be reversible, as far as we know now.

Panel members noted they were not able to adequately articulate the intangible qualities of "wildness" that are highly valued by some members of the public. There was some interest in encouraging social research to pursue greater understanding of these values and to determine how widely they are held.

Possible Strategies Considered by the Expert Panel Review

From their discussions, the group identified the following possible strategies:

1) Continue collaring and testing a few wolves (two per year) as now. *This strategy was considered attractive by the panel because of the value and success of past research, but the low number of collared wolves limits data collection and research flexibility.*

2) Do no handling except under specified conditions (for example, a significant reduction in wolf numbers). *This strategy was rejected by the panel because it would result in the loss of information related to genetic decay tracking of the population and only an "after the fact" response to disease.*

3) Do no handling under any conditions. *The panel rejected this strategy because the science done with handling has had benefit, and because, in case of a population crash, managers and researchers would have no options for response.*

4) Increase amount of handling in order to improve data collecting (maintain two collared wolves per pack). *This strategy was attractive to the panel because of the tangible benefits of better data, but more handling could increase the risk of injury or mortality.*

5) Continue to handle wolves for a set time period, while looking for data collecting techniques that do not require handling. *This strategy would maintain the genetic data collection, but could help meet an eventual goal of phasing out handling.*

Recommendation of the Expert Panel

Following much discussion, the expert panel agreed on:

- Continue handling wolves for the next five years (2000-2004). Up to four wolves per year should be handled, not to exceed two collared wolves per pack, and no more than 12 wolves total over the five-year period (this is close to the capture rate during 1988-1993, but allows more flexibility each year). These numbers reflect the desire to maximize handling opportunities during livetrapping efforts, given the logistical difficulties of trapping operations in the Park, while still handling only the minimum number of animals necessary for information purposes.
- Over the five years, aggressively look for data gathering techniques that would not require handling, by challenging the NPS and the scientific community to develop and study these new techniques. There are promising techniques being tested elsewhere on other mammals, including the use of hair and fecal material to obtain genetics information. The NPS would have an opportunity to exhibit leadership in this area for wolves.
- If, within the five years, new techniques are found for acquiring genetic data without handling the wolves, convene a panel to evaluate whether disease and counting benefits are worth the continued handling of wolves.
- If no new techniques are found within the five years, convene a panel to reevaluate the handling issue.
- If a sudden population crash occurs, explore different strategies that may be needed to respond to the situation.

Discussion

Park management annually faced an uncomfortable issue of how to balance the research needs of a successful and publicly popular wolf research program with the need to consider the minimal research methods consistent with wilderness values. The use of an expert review panel provided the two parties closest to the issue—the NPS and the principal investigator—an opportunity to step away from the debate and obtain guidance relevant to the issue. Although, ultimately, the final decision on whether to continue wolf handling practices rests with Park management, the independent scientific review provided an unbiased recommendation for consideration.

In this case the review panel process was considered a valuable tool to aid Park management. Park management has largely adopted the panel's recommendations, with the exception of being unwilling to permit the live-capture of more than two wolves per year, reflecting a very conservative attitude intended to minimize possible injury to individual animals (Isle Royale National Park 1999b). The key information needs critical to the research program will remain obtainable.

The public attitude regarding the handling of wildlife with the Park wilderness was identified by the panel as a key information need. The lack of this information hampered the panel review of this issue. Informal discussion with some Park visitors in the summer of 1999 indicated that many visitors are willing to accept some impacts to their wilderness experience, such as seeing collared animals or knowing

wildlife is being handled, provided they are informed of the efforts and agree the research is necessary. However, many other visitors expressed concern regarding wildlife handling activities for the reasons of impacts on the wilderness values of the Park. The recommended public attitude research would more clearly identify how serious the wildlife handling issue is outside of the NPS agency.

For the near term at least, wolf handling will remain an important element of the wolf research program. Meanwhile, the challenge of balancing the wilderness values of a wild wolf population at Isle Royale with the agency and research needs will continue to provide a fascinating case history for review.

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References

Allen, D.L. 1979. Wolves of Minong. Houghton Mifflin Company. 499 p.

Allen, D.L.; Mech, L. D. 1963. Wolves versus moose on Isle Royale. National Geographic. Feb. 1963: 200-219.

Clark, C. 1995. Archeological survey and testing at Isle Royale National Park, 1987-1990 season. Midwest Archeological Center Occasional Studies in Anthropology No. 32. 231 p.

Isle Royale National Park. 1999a. Internal memo, Report on review of wolf handling. Isle Royale National Park, Houghton, MI. 7 p.

Isle Royale National Park. 1999b. Internal memo, Wolf handling. Isle Royale National Park, Houghton, MI. 1 p.

Jordan, P.A.; Shelton, P.C.; Allen, D.L. Numbers, turnover, and social structure of the Isle Royale wolf population. American Zoologist 7:233-252.

Lehman, N.; Eisenhawer, A.; Hansen, K.; Mech, L.D.; Peterson, R.O.;. Gogan, P.J.P.; Wayne. R. K. 1991. Introgression of coyote mitochondrial DNA into sympatric North American gray wolf populations. Evolution 45(1):104-119.

Mech, L.D. 1966. The wolves of Isle Royale. Fauna of the National Parks of the United States, Fauna Series 7. 210 p.

Meffe, G.K.; Boersma, P. D.; Murphy, D.D.; Noon, B.D.; Pulliam, H.R.; Soule, M.E.; Waller, D.M. 1998. Independent scientific review in natural resource management. Conservation Biology 12: 268-270.

Murie, A. 1935. Preservation of wilderness on Isle Royale. Excerpted in Horizons, the newsletter of the Sigurd Olson Environmental Institute, Ashland, WI. Summer 1991.

Peterson, R.O. 1977. Wolf ecology and prey relationships on Isle Royale. National Park Service Scientific Monograph Series, No. 11. 210 p.

Peterson, R.O. 1999a. Ecological studies of wolves on Isle Royale, Annual Report 1998-99. Michigan Technological University, Houghton, MI.

Peterson, R.O. 1999b. Wolf-moose interaction on Isle Royale: the end of natural regulation? Ecological Applications 9(1):10-16.

Peterson, R.O.; Page, R.E. 1988. The rise and fall of Isle Royale wolves, 1975-1986. Journal of Mammology 69(1): 89-99.

Peterson, R.O.; Thomas, N.J.; Thurber, J.M.; Vucetich, J.A.; Waite, T.A. 1998. Population limitation and the wolves of Isle Royale. Journal of Mammology 79: 828-841.

Turner, J. 1997. The Abstract Wild. University of Arizona Press. 136 p.

U.S. Department of the Interior, National Park Service. 1988. Management Policies.

U.S. Department of the Interior, National Park Service. 1999. Final General Management Plan and Environmental Impact Statement, Isle Royale National Park, Michigan. Houghton, MI. 222 p.

Vucetich, J.A; Vucetich, L.M. 1999. Unpublished data.

Wayne, R.K.; Gilbert, D.A.; Lehman, N.; Hansen, K.; Eisenhawer, A.; Girman, D.;. Peterson, R.O. ; Mech, L.D.; Gogan, P.J.P.; Seal, U.S.; Krumenaker, R.J. 1991. Conservation genetics of the endangered Isle Royale gray wolf. Conservation Biology. 5:41-51.

Wilderness Act. 1964. Public Law 88-577.

The Challenge of Scientific Activities in Wilderness

David J. Parsons

Abstract—Science is an appropriate and necessary use of wilderness. The long-term protection of wilderness, including decisions related to the planning and management of wilderness resources, use and values, requires an understanding often available only through scientific investigation. In addition, wilderness provides opportunities for scientific understanding not available in other, less protected areas. Yet the acquisition of scientific information often requires activities that affect wilderness resources and values. Decisions about what scientific activities are appropriate and necessary in wilderness require consideration of apparently conflicting mandates, as well as the balancing of the benefits and impacts of proposed actions. Improved communication and cooperation between wilderness managers and scientists is necessary to assure the best possible science with the minimum possible impact.

The approval and conduct of scientific activities (research, monitoring and inventory) in wilderness present challenges to both managers and scientists. Despite wide recognition of the value of science, concern over the appropriateness and impacts of scientific activities have resulted in the denial of many proposals to work in wilderness. As a result, some scientists perceive wilderness managers as unable (unwilling?) to objectively consider the benefits of a proposed study beyond the narrow needs of the local area. Perceptions of a lack of management interest or understanding of science have led some scientists to avoid working in wilderness. Managers, in turn, become frustrated by a perceived inability (or unwillingness?) of some scientists to understand the philosophical basis of wilderness management and the significance of the impacts their activities may cause. Some scientists consider their research so important that they can't understand why it might not be appropriate or acceptable, even in wilderness. All too often, the result has been the avoidance of wilderness by scientists (Franklin 1987), resulting in less than adequate information and, ultimately, lost opportunities for both science and wilderness.

Concerns about the conduct of science in wilderness most frequently focus on the biophysical, social and aesthetic impacts of scientific activities, including the use of motorized equipment (Parsons and Graber 1991). Examples of the many potential impacts of scientific activities are presented in table 1. These include visual as well as physical and ecological impacts; impacts to individual perceptions of wilderness as well as to ecosystem elements and processes. These are the impacts that frequently lead to denial of research permits, in turn feeding scientists' perceptions that management neither understands nor supports the importance of science.

This paper considers the values of science to wilderness as well as the values of wilderness to science. Relevant legislation and policy as well as scientific understanding of the value of studying wild systems are reviewed. Concerns over the impacts of conducting science in wilderness are also considered. The dilemma of how to balance the scientific values of wilderness with concerns over the impacts of science is discussed, and suggestions are made on how to maximize scientific benefits while assuring the continued integrity of wilderness.

Historical Perspectives on Wilderness Science

Authorizing legislation for most large national parks, the organic acts creating the federal land management agencies and even the 1964 Wilderness Act were largely crafted in a climate that did not recognize the ecological complexity of natural ecosystems or the value of protected areas to regional and global conservation (Christensen 1988). Designation of an area was generally considered adequate to "protect" it from change (Graber 1995). Since little recognition was given to the importance of understanding wild ecosystems, little attention was given to the scientific investigation or monitoring of resource conditions. Scientific benefits accrued largely from limited natural history observations and collections.

In recent years, the context for managing wilderness has changed dramatically. Recognition of the temporal and

Table 1—Representative examples of issues and impacts associated with the conduct of scientific activities in wilderness.

Impact/activity	Example
Live trapping	Wolves, Isle Royale
Radio collars	Bighorn, Grand Tetons
Plot markers	FIA, FS wilderness
Helicopter access	Lake chemistry sampling, FS/NPS
Equipment transport/caches	Death Valley
Fire scar wedges	NPS/FS wildernesses
Wildlife guzzlers	BLM/FWS desert wildernesses
Overflights	Wildlife surveys
Visitor surveys	Beepers, Okefenokee
Prescribed fire	FS wilderness
Mechanical thinning	Grand Canyon, Bandelier
Seismic equipment	Death Valley
Snow and stream gauges	Various
Weather stations	Various

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spatial complexity of natural ecosystems and the importance of relatively undisturbed areas to the preservation of biodiversity, together with increased public scrutiny of management decisions, have greatly complicated the role of the wilderness manager. One consequence has been increased pressure to base policy and management decisions on sound science (Christensen and others 1996). However, despite a recognized need for science, "relatively little scientific use has been made of wilderness" (Franklin 1987).

Science and Wilderness

The scientific value of wild areas has long been recognized. Such early conservationists as John Muir and George Perkins Marsh recognized the importance of protected areas to science (Nash 1982). In the 1920s some of the most eminent ecologists of the day called for the setting aside of large natural areas for their scientific value (Adams 1929, Leopold 1921, Sumner 1921). In 1941, Aldo Leopold (1941) stated that "all wilderness areas...have a large value to land science." A year later, E. L. Sumner (1942) wrote "to the men of science, the dwindling wilderness is an irreplaceable reservoir of information on natural conditions." The 1959 Sixth Biennial Wilderness Conference was titled "The Meaning of Wilderness to Science." It offered numerous testimonies to both the value of science to wilderness and of wilderness to science (Brower 1960). Building on a number of earlier reviews of the National Park Service's science program, a 1992 report by the National Academy of Sciences emphasized the importance of science to parks, and, by implication, wilderness, and parks to science (National Research Council 1992). It noted that protecting the resources of parks and wilderness "requires scientific knowledge, and an increasingly sophisticated application of that knowledge. The problems faced...today are too many and too complex to solve without the help of science." More recently, Cole and Landres (1996) provided a thorough review of needed research to support wilderness management.

Although there is a well-documented history of the value of science as an essential tool to informed management of wilderness (Lucas 1986, 1987), the broader values of wilderness to science have not been as widely developed. There is wide recognition of the value of wild areas for teaching about basic ecological processes, serving as reservoirs of biotic diversity and species refugia, and as baselines against which to evaluate the impacts of human activities (Franklin 1981, National Research Council 1992, Sinclair 1998); yet wilderness has not been widely used for such purposes (Franklin 1987). As early as 1959, Cain (1960) recognized the difficulties of expounding on the values of wilderness for scientific research when little significant research had been done there. This continues to be a dilemma for those advocating the need for greater scientific use of wilderness.

The 1964 Wilderness Act (P.L. 88-577) is often interpreted as prohibiting all but the most essential of activities. As in the case of those who view wilderness as areas apart from humans, areas we neither know nor should know much about, the tendency of such thinking is to restrict scientific activities to those absolutely necessary for protection of the immediate area. However, an interesting insight into the thinking of Howard Zahniser, chief architect of the Wilderness Act, about the scientific use of wilderness is found in his comments after a 1959 presentation by Luna Leopold (1960) on the value of wilderness for hydrological research. Zahniser commented about the intended "multiplicity of purposes" for the proposed wilderness system, including "to serve the...scientific...needs of the people" (Leopold 1960). In comments to Leopold, he raised specific concerns about whether areas "established for this multiplicity of purposes" would also be able to adequately serve the scientific needs of the people. He asked "do you think the recreational uses...in these areas would necessarily interfere with the establishment of these bench mark stations and other installations for scientific purposes?" Leopold responded that he thought modest recreational use would be compatible with hydrological research. Zahniser followed up by suggesting the need "to give some distinctive attention to the use of these areas for scientific purposes" and for "some thoughtful program for seeing that these areas are so used." It is clear from this discussion that the chief proponent and architect of the Wilderness Act viewed science, including scientific installations, as an appropriate and desired use of the proposed wilderness system.

Analysis of the legislative history of wilderness strongly supports the value and use of wilderness for science. The 1964 Wilderness Act recognized the value of wilderness to science by stating in Section 4 (b) that "scientific use" is one of the "public purposes" of wilderness. Scientific use was mentioned in equal terms as recreational, scenic, educational, conservation and historical uses. Recognition of the importance of wilderness to science is further supported by statements about the important scientific values of the proposed wilderness system made by Frank Church, acting committee chairman for the Senate Committee on Interior and Insular Affairs, during Committee Explanations (U.S. Congress 1963) and statements made by various sponsors during floor debate on the Wilderness Act (e.g., U.S. Congress 1964). The 1994 California Desert Wilderness Act (P.L. 103-433) is even more explicit in stating that a primary purpose of wilderness is to "retain and enhance opportunities for scientific research in undisturbed ecosystems."

Discussions and hearings leading up to the designation of Hawaii Volcanoes National Park as wilderness in 1978 directly confronted the need for mechanized equipment, mechanical access (helicopters and 4-wheel drive vehicles), and fences as the minimum tools for managing Hawaiian wilderness (including prediction of volcanic eruptions and control of exotic species). Since these activities were agreed to by all interested parties as appropriate and necessary, the NPS proposed "special conditions" to recognize and allow those activities that might be considered to be in conflict with the Wilderness Act. During the E.I.S. process, testimony from environmental groups agreed with the need for these activities, and, in fact, often argued for the necessity of them. At least one national environmental group argued against the need for special conditions as they believed the Wilderness Act was sufficiently broad and flexible to allow scientific and management activities without special conditions (B. Harry, personal communication). They apparently felt the precedent of such conditions might limit similar activities in other wildernesses. Congress passed the Hawaiian wilderness legislation without the special provisions. The interpretation of this action by the then superintendent of Hawaii Volcanoes National

Park, based on his discussions with the Hawaiian Congressional delegation and others on the Hill, was that "they made a clear statement to all wilderness managers that science and native ecosystem preservation and restoration are fundamental to wilderness as contemplated under the 1964 Act" (Harry, personal communication).

Recognition of the importance of wilderness science is more recently evidenced by the fact that since 1993, the four federal wilderness management agencies (USDI Bureau of Land Management, U.S. Fish and Wildlife Service, USDA Forest Service and USDI National Park Service) and the U.S. Geological Survey's Biological Resources Division have cooperatively supported efforts to coordinate and facilitate wilderness research efforts. This is accomplished through support of the interagency Aldo Leopold Wilderness Research Institute, in Missoula, Montana; the only research group in the nation dedicated to developing the knowledge needed to improve management of wilderness and other natural areas (see www.wilderness.net/leopold).

Policies and Guidelines

Although the Wilderness Act and subsequent wilderness legislation clearly recognize the validity of science as an appropriate use of wilderness, they provide only broad philosophical guidance for establishing specific policy or guidelines for the conduct of science. For example, although the wilderness policies of all four wilderness management agencies endorse science as an appropriate use of wilderness (table 2), they emphasize restrictions to scientific use. Agency wilderness policies tend to focus on whether there is an alternative to conducting a study in wilderness (that is, can it be done elsewhere?), its impacts on wilderness values, whether it will interfere with recreational or other purposes of the area, and the importance of the study to management of the local area (see table 2 for examples of policy wording). There is little discussion in policy statements of the value of the information to be derived, what might be lost by doing the study elsewhere, or guidance on how to evaluate the "importance" or benefits of a proposed study. The policies are particularly quiet on the subject of benefits for broader regional or societal needs, and there is no mention of potential impacts of recreational or other permitted uses on scientific values. The overall impression is that science is not a preferred use and should be permitted only when absolutely necessary and when impacts can be avoided or minimized.

Policy statements regarding what is appropriate and acceptable leave considerable latitude for interpretation. The result has been development of rather distinct policies and practices, as well as quite different management philosophies, between the four wilderness management agencies (Allin 1985). For example, although the wilderness policies of all four agencies emphasize the minimum requirement (or minimum tool) concept, they differ considerably in how they interpret what the "minimum" is. The Forest Service has developed a reputation of more strict interpretation of "minimum" and commonly prohibits some activities that the Department of Interior agencies are more likely to permit (Franklin 1981).

Agency guidelines are often so broad that local managers have discretion to make decisions on the appropriateness of many types of science activities, including changing decisions made by earlier administrators. This can lead to inconsistencies not only between agencies, but among units of the same agency. Large-scale studies that require work on multiple jurisdictions can be especially hampered by inconsistent requirements between adjacent areas. There is also a general lack of guidance regarding how proposals for scientific activities should be developed and what criteria will be used in their evaluation. Adding to the confusion faced by scientists proposing to work in wilderness, approval authority for research permits varies from state offices (BLM) to park superintendents (NPS) to districts (FS), often resting with individuals with little understanding of science.

Concern over how federal agencies evaluate science proposals (see, for example, Eichelberger and Sattler 1994) led to a 1995 National Academy of Sciences workshop to review the lack of a consistent policy for the conduct of science on protected public lands. This workshop resulted in a recommendation to conduct a National Academy review of the situation that has yet to be acted on.

In a recent survey of units in the four wilderness management agencies, I was able to identify only a few National Park Service examples of areas with detailed guidelines or formats for the proposal or approval of research projects in wilderness. Shenandoah and Grand Canyon National Parks are two areas that have developed guidelines to help potential investigators understand the concerns and constraints of wilderness managers. In both of these cases, the parks specifically encourage research and monitoring activities in wilderness, recognizing that some important work may require impacts, including the use of motorized devices. These parks provide for review of the benefits of proposed

Table 2—Selected excerpts regarding research and scientific activities from the most recent wilderness policies of the four wilderness management agencies[a].

General policy
BLM[b]: "...provide opportunities for research and scientific activities...for study of natural environments and ecosystems" (1983).
FS "...provide appropriate opportunity for scientific studies that are dependent on a wilderness environment" (1990).
FWS "...provide opportunities for research, solitude, and recreation" (1986).
NPS "...will fully support the value of wilderness areas as natural outdoor laboratories" (1988).
Examples of policy constraints
BLM "provided that wilderness is essential to results of such research, and wilderness values would not be jeopardized."
FS "Do not allow the use of motorized equipment or mechanical transport unless the research is essential to meet minimum requirements for administration of the area as wilderness and cannot be done in another way."
FWS: "where...compatible with refuge objectives."
NPS: "The project will not interfere with recreational, scenic, or conservation purposes of the wilderness."

[a]As of the spring of 1999 the BLM, FS, and NPS were all actively revising their wilderness policies.

[b]BLM = Bureau of Land Management, FWS = Fish and Wildlife Service, FS = Forest Service, NPS = National Park Service.

studies, including consideration of methodologies that specifically consider wilderness values. No examples were found of national forests, wildlife refuges or BLM districts with equivalent guidelines. Consistency in interpretation and application of laws, policies and guidelines would help those wishing to work in wilderness to better understand and comply with the applicable rules.

Managing Scientific Use

If science is to be recognized as a valid purpose and use of wilderness that, like recreation, is encouraged as long as potential benefits outweigh impacts, it will be necessary to overcome the perception that science is an intrusion that should only be permitted if essential to management of the local area. This perception is based in part on the tendency to apply Section 4(c) of the Wilderness Act, which prohibits motorized equipment, mechanical transport and structures and installations except under specified conditions, as a blanket restriction to all science. Reestablishing science as a primary use of wilderness will require renewed recognition of the value of wilderness to science, improved understanding and communication between wilderness managers and scientists, and an improved process for evaluating proposals for scientific activities. Such recognition could have profound effects on how wilderness is utilized to improve knowledge of our natural world and the impacts of human activities on it. It would emphasize the important role for wilderness in providing the understanding necessary to protect natural systems around the globe, as well as improve the information available to manage more impacted areas.

Graber (1988) suggested that scientific research should be permitted "for its own sake" as long as the resource costs are commensurate with those of other kinds of wilderness use, such as recreation. For example, he suggested approval of research activities with minimal or temporary impacts similar to those caused by recreation users. Thus, when considering proposals for research activities, the emphasis should not be on whether it is an appropriate use, but on how to maximize the benefits to be obtained and minimize or mitigate impacts caused by the use. Of course, it is important that scientists proposing to work in wilderness understand wilderness values and concerns about impacts to resources and values - much as recreational users are expected to understand and practice low-impact ethics. If science is treated as a valid and primary purpose of wilderness, scientists will be expected to comply with and support low-impact activities.

In the case of scientific activities with the potential for significant impacts, those impacts must be compared to the benefits to be derived. Again, if initial discussions focus on benefits and then proceed to options for minimizing and mitigating impacts, the chances of reaching agreement between managers and scientists are greatly improved. In the long term, this improved communication will assure the greatest benefit to wilderness, science and society. Only those projects with minimal benefits and significant impacts should be summarily rejected.

Zoning

One approach to encouraging greater scientific use of wilderness might involve managing different wildernesses, or portions of wildernesses, for different levels of scientific activity. Similar recommendations have been made for managing wildernesses for different use levels, impacts or types of management (Cole 1996). In the case of science, some wildernesses, or portions of wildernesses, could be managed primarily for their scientific value. In such cases, consideration should be given to whether recreation or other uses that might impact the scientific values of the areas should be restricted. This would be a different type of wilderness than has been typical in the United States, but one that is not inconsistent with protected area classifications in other parts of the world (Ostergren 1998).

Collaboration

Wilderness managers are often forced to make difficult decisions about contentious issues - from implementing use restrictions to the appropriateness of using prescribed fire to restore natural fire regimes. In many cases, these decisions require consideration of conflicting mandates, such as facilitating recreation use while managing for natural ecosystems. In today's world, where interest groups are determined to protect their special causes, it is more important than ever that such decisions be based on solid science. To assure that the best possible science is available when needed, science and management must be brought into a partnership built on mutual understanding and trust. The best way to accomplish this is through open communication, including efforts to understand the context and constraints under which others operate. Improved understanding and communication between wilderness managers and scientists increase the likelihood that useful products will be obtained and impacts will be minimized.

A recently proposed geology project in Death Valley National Park in California exemplifies a situation where early communication brought about a compromise between the need to use wilderness for important science that is of little immediate value to the park (understanding of plate tectonics) and the sensitive wilderness values of the area. In this case, discussions between scientists and wilderness managers were able to identify a number of changes needed in the initial proposal to significantly reduce the impacts of the study without severely compromising the anticipated scientific benefits. The resulting compromise was a win-win situation for wilderness as well as scientists and managers (R. Anderson, personal communication). This contrasts sharply with the confrontation between the National Park Service and geologists proposing to study vulcanism at Katmai National Park in the early 1990s which ended with the scientists withdrawing their research application in frustration (see Eichelberger and Sattler 1994).

Guidelines

There is a clear need for both managers and scientists to have access to guidelines specific to the proposal, evaluation

and conduct of scientific activities in wilderness. Such guidelines should help managers recognize and evaluate the benefits of science to wilderness as well as to larger conservation issues, while helping scientists better understand the constraints on managers and the basis for concern over the impacts science can have. Guidelines for managers should address the value of wilderness to science as well as the value of science to wilderness. They should emphasize that large, relatively undisturbed natural areas are increasingly important to the understanding of regional and global environmental problems. Since the scientific value of wilderness in the future is impossible to fully anticipate, it is especially important that today's managers recognize that the wilderness resource they are responsible for may hold keys to the understanding and future sustainability of regional and global environments. A proposed framework for evaluating scientific proposals (Landres, this proceedings) provides valuable guidance on how to think about the benefits as well as the impacts of scientific activities, including those benefits important beyond the immediate area.

Guidelines for scientists interested in working in wilderness must address the concerns of managing and protecting "untrammeled" ecosystems with "the imprint of man's work substantially unnoticeable." Such guidelines should detail concerns about impacts to ecosystem elements and processes, as well as to opportunities for "solitude or a primitive and unconfined type of recreation." They should specifically address the information required in an application for a research permit, including discussion of such issues as access to sites, ground disturbance, use of equipment and animal welfare. They should fully address options for minimizing or mitigating impacts. Table 3 itemizes a number of options for mitigating impacts of scientific activities. Guidelines for scientists should serve as principles of conduct, outlining what is and is not appropriate behavior in the conduct of wilderness science. Access to such information should help assure that proposals for work in wilderness are responsive to wilderness concerns, increase the chances of proposals being approved and, by so doing, avoid much of the acrimony that has accompanied past efforts of scientists to work in wilderness. Successful examples of such guidance include "Principles for the Conduct of Research in the Arctic" prepared by the Interagency Arctic Research Policy Committee of the National Science Foundation's Office of Polar Programs (IARPC 1992) and the Protocol on Environmental Protection, which governs activities in the Antarctic (National Research Council 1993).

As of the spring of 1999, the National Park Service is on the verge of adopting national guidelines and protocols for the application and approval of research and collecting permits (J. Bayless, personal communication). These guidelines itemize the factors to be considered in the evaluation of proposals; they provide the information that should be included in an application for a permit. Although the guidelines do not specifically address wilderness concerns, the factors addressed include many of the issues of greatest concern to wilderness managers: safety, access to study sites, use of motorized or other equipment, use of chemicals, ground disturbance and animal welfare. They also address the need to adhere to "minimum requirement" and "minimum tool" concepts if the activities will be conducted in areas administered as designated, proposed or potential wilderness. Such guidance represents a major advance in improving communication with the scientific community.

Table 3—Options for mitigating impacts of science.

1. Siting of equipment or activities to minimize visual intrusion
2. Timing of activities to avoid high visitor use periods
3. Use of primitive tools
4. Nondestructive sampling
5. Capitalize on education opportunities

Conclusions

It is clear that science is both a statutory purpose of wilderness and critical to the long-term protection of wilderness. It will be impossible to assure the long-term preservation of wilderness without a thorough understanding of wilderness resources and values, including public perceptions and desires, and ecosystem elements and processes, as well as threats to those resources and values. This requires the protection of scientific values of wilderness, as well as support for and accommodation of the use of wilderness for science. Given this understanding, I argue that the conduct of science should be viewed as every bit as appropriate and desirable as other statutory uses of wilderness. Like recreation, it should be permitted to the extent that wilderness resources and values are not unduly compromised. This interpretation appears to be consistent with the thinking of Howard Zahniser, the principal architect of the Wilderness Act, as well the understanding of legislative intent held by principal figures involved in the 1970s Hawaiian wilderness proposals. However, this recognition does not mean that scientists should be given carte blanche to conduct scientific activities where, when and how they propose. It is critical that research and other proposed scientific activities in wilderness be carefully evaluated to assure that the benefits outweigh the impacts.

Improved understanding and communication between wilderness managers and scientists are essential to development of a science-friendly environment in which the best possible science is conducted with the minimum possible impact. To be fully effective, this communication must begin early in the project conceptualization and proposal process and continue throughout the life of the project, including the application of results to policy or practice. Federal wilderness management agencies need to more explicitly articulate their recognition and support of the scientific value and use of wilderness in their policies, guidelines and practices. Scientists must pay attention to and try to understand the concerns and constraints of wilderness managers, as well as strive to reduce or mitigate the impacts of proposed activities. Managers and scientists should work together to develop guidelines to help both groups better articulate their interests and needs in a wilderness context. Guidelines for managers should clarify the appropriateness of various scientific activities and provide guidance on how to evaluate proposals. Guidelines for scientists should clarify the concerns of wilderness

managers, articulate the issues that need to be addressed in a proposal, and outline principles of conduct for scientific activities in wilderness. Such cooperation will help us think about wilderness and science as mutually supportive and, in so doing, help assure the long-term preservation of wilderness.

References

Adams, C. C. 1929. The importance of preserving wilderness conditions. New York State Museum Bulletin 279:37-44.

Allin, C.W. 1985. Hidden agendas in wilderness management. Parks and Recreation 20(5):62-65.

Anderson, Richard. 1999. [Personal communication]. March 25. Death Valley, CA. National Park Service, Death Valley National Park.

Bayless, Jonathon. 1999. [Personal communication]. March 25. San Francisco, CA. National Park Service, Western Regional Office.

Brower, D. 1960. The Meaning of Wilderness to Science. Sierra Club, San Francisco, CA. 129 p.

Cain, S. A. 1960. Ecological islands as natural laboratories. Pp. 18-31 in Brower, D. (ed.) The Meaning of Wilderness to Science. Sierra Club, San Francisco, CA.

Christensen, N. L. 1988. Succession and natural disturbance: paradigms, problems, and preservation of natural ecosystems. Pp. 62-86 in Agee, J. K. and D. R. Johnson (eds.) Ecosystem Management for Parks and Wilderness. University of Washington Press, Seattle, WA.

Christensen, N. L.; A.M. Bartuska; J.H. Brown; S. Carpenter; C. D'Antonio; R. Francis; J.F. Franklin; J.A. MacMahon; R.F. Noss; D.J. Parsons; C.H. Peterson M.G. Turner; R.G. Woodmansee. 1996. The report of the Ecological Society of America committee on the scientific basis for ecosystem management. Ecological Applications 6(3):665-691.

Cole, D. N. 1996. Ecological manipulation in wilderness - an emerging management dilemma. International Journal of Wilderness 2(1):15-19.

Cole, D. N. and P. B. Landres. 1996. Threats to wilderness ecosystems: impacts and research needs. Ecological Applications 6(1):168-184.

Eichelberger, J. and A. Sattler. 1994. Conflict of values necessitates public lands research policy. EOS, Transactions, American Geophysical Union 75(43):505-508.

Franklin, J. F. 1981. Wilderness for baseline ecosystem studies. Pp. 37-48 in Proceedings XVII IUFRO World Congress, Division 1. Forestry and Forest Products Research Institute. Ibaraki, Japan.

Franklin, J. F. 1987. Scientific use of wilderness. Pp. 42-46 in Lucas, R. C. (Compiler), Proceedings - National Wilderness Research Conference: issues, state-of-knowledge, future directions. USDA Forest Service, General Tech. Report INT-220. Ogden, UT.

Graber, D. M. 1988. The role of research in wilderness. The George Wright Forum. 5(4):55-59.

Graber, D. M. 1995. Resolute biocentrism: managing for wildness in national parks. Pp. 123-135 in Soule, M. E. and G. Lease (eds.) Nature and Reality: Critiques of Postmodernism Deconstruction. Island Press, Washington, D.C.

Harry, B. 1999. [Personal communication]. May 28, letter to David J. Parsons. Written from USDI National Park Service, Honolulu, Hawaii.

IARPC (Interagency Arctic Research Policy Committee). 1992. Principles for the Conduct of Research in the Arctic. Arctic Research in the United States 6:78-79.

Landres, P.B. [In press]. A framework for evaluating proposals for scientific activities in wilderness. In: McCool, Stephen F.; Cole, David N.; Borrie, William T.; O'Loughlin, Jennifer, comps. 2000. Wilderness science in a time of change conference—Volume 3: Wilderness as a place for scientific inquiry; 1999 May 23-27; Missoula, MT. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Leopold, A. 1921. The wilderness and its place in forest recreational policy. Journal of Forestry 19(7):718-721.

Leopold, A. 1941. Wilderness as a land laboratory. Living Wilderness 6:3.

Leopold, L. B. 1960. Ecological systems and the water resource. Pp. 32-45 in Brower, D. (ed.) The Meaning of Wilderness to Science. Sierra Club, San Francisco, CA.

Lucas, R. C. 1986. Proceedings—national wilderness research conference: current research. USDA Forest Service, General Tech. Report INT-220. Ogden, UT. 553 p.

Lucas, R. C. 1987. Proceedings—national wilderness research conference: issues, state-of-knowledge, future directions. USDA Forest Service, General Tech. Report INT-220. Ogden, UT. 369 p.

Nash, R. 1982. Wilderness and the American Mind. 3rd edition. Yale University Press, New Haven, CN. 425 p.

National Research Council. 1992. Science and the National Parks. National Academy Press, Washington, D.C. 122p.

National Research Council. 1993. Science and Stewardship in the Antarctic. National Academy Press, Washington, D.C. 107 p.

Ostergren, D. 1998. System in peril—a case study of six Siberian nature preserves. International Journal of Wilderness 4(3):12-17.

Parsons, D. J. 1998. Scientific activities in wilderness. International Journal of Wilderness 4(1):10-13.

Parsons, D. J. and D. M. Graber. 1991. Horses, helicopters and hi-tech: managing science in wilderness. Pp. 90-94 in Reed, P. C. (Compiler), Preparing to manage wilderness in the 21st Century. USDA Gen. Tech. Rep. SE-66.

Sinclair, A.R.E. 1998. Natural regulation of ecosystems in protected areas as ecological baselines. Wildlife Society Bulletin 26(3):399-409.

Sumner, F. B. 1921. The responsibility of the biologist in the matter of preserving natural conditions. Science 54:39-43.

Sumner, E. L. 1942. The biology of wilderness protection. Sierra Club Bulletin 27(8):14-22.

U.S. Congress. 1963. Senate Report 109 on S.4 of the Senate Committee on Interior and Insular Affairs. 88th Congress. 1st session. April 3, 1963.

U.S. Congress. 1964. Congressional Record. Vol 110, Part 13. 88th Congress 2nd session. July 30, 1964.

Research Protocols in National Park Service Wilderness

Jim Walters

Abstract—While the National Park Service encourages the use of its wilderness resource for research, management policies require that all research apply "minimum requirement" protocols to determine: 1) if the research is needed to support the purposes of wilderness and, 2) if it is appropriate, determine the minimum tool needed to accomplish the work.

The National Park Service (NPS) currently administers 43,079,219 acres of designated wilderness within 44 national park areas and has an additional 16,000,000+ acres identified as recommended or potential wilderness in 31 additional park units. The number and types of requests by NPS scientists and academic institutions wanting to conduct research within park wilderness makes it necessary for managers to evaluate the merits of individual research projects against their responsibilities to preserve the letter and spirit of wilderness as defined by the 1964 Wilderness Act.

In 1997 the National Park Service adopted a three-tiered Directive System regulating the issuance of Service guidelines.

Level 1 instructions consists of policies included within the NPS *Management Policies* handbook. **Level 2** guidelines are issued as "Director's Orders." Director's Order's articulate new or revised policy on an interim basis between the publication date of NPS Management Policies and are intended to provide specific instructions and outline requirements applicable to NPS functions, programs, and activities. Director's Order's also provide a means by which the Director can delegate specific authorities and responsibilities. The main target audience for Director's Orders is park superintendents and managers. **Level 3** materials include handbooks, reference manuals and other documents containing comprehensive information in support of field activities and planning operations.

The need for more specific guidelines directing the administration of NPS research activities in wilderness was identified by field staff as one of several critical issues which needed to be addressed in the agencies revised Management Policies handbook.

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National Park Service Wilderness Research Protocols

The National Park Service recently completed *Reference Manual #41: Wilderness Preservation and Management* which includes both the updated and revised management policies (*Management Policies Chapter 6: Wilderness Preservation and Management*) and Director's Orders intended to instruct the parks on the specific implementation of policy guidelines. Section 6.3.10 (Scientific Activities) of the policies statement includes protocols for evaluating and approving research activities within wilderness. The policy document attempts to establish a positive tone addressing the issue of research in wilderness by stating:

> "The statutory purposes of wilderness include scientific activities, and these activities are permitted when consistent with the agencies responsibilities to preserve and manage wilderness. The National Park Service has a responsibility to support appropriate scientific activities in wilderness, and to use science to improve wilderness management. The Service further recognizes that appropriate scientific activities may be critical to the long-term preservation of wilderness.

The policy statement also identifies conditions under which research activities, including those involving prohibitions identified in Section 4(c) of the Wilderness Act (no commercial enterprises, no permanent roads, no motor vehicles, no landing of aircraft, no other form of mechanical transport) may be permitted within wilderness as the "minimum requirement" needed for the administration of the area. These research conditions include:

- The desired information is essential for the administration or preservation of wilderness, and the project cannot be reasonably modified to eliminate or reduce the nonconforming wilderness use. The preservation of wilderness resources and character will be given significantly more weight than economic efficiency and/or convenience.
- The needed information cannot be obtained from outside the wilderness area or from outside the park without significant loss of precision and applicability.
- NEPA (including the completion of a documented categorical exclusions, environmental assessments/findings of no significant impact, or environmental impact statements/records of decision) and other regulatory compliance is accomplished and documented.
- All scientific activities will be accomplished in accordance with stipulations adopted at the time the research permit is approved. Later requests for exceptions to the Wilderness Act will require additional review.

- The project will not significantly interfere with other wilderness purposes (recreational, scenic, educational, conservation or historical) over a broad area or for a long period of time.
- The project information is determined to be necessary to the understanding, health, or management of the wilderness area.
- Implementation of the project will apply the minimum requirement concept.

The revised policies further provide for the installation of research and monitoring devices (video cameras, data loggers, meteorological stations) within wilderness if: 1) the desired information is essential for the administration and preservation of wilderness and cannot be obtained from a location outside of wilderness without significant loss of precision and applicability, and 2) the proposed device is the minimum requirement necessary to accomplish the research objective safely.

These policies are designed to ensure that research projects, regardless of the agency or institution conducting the research, apply a minimum requirement assessment similar to that applied to all other management actions affecting wilderness.

Instructions for performing a minimum requirement assessment, including those needed for research projects, are included as a separate section (Chapter 6. Section 6.3.6, *Minimum Requirement*) within the revised policy statements. The minimum requirement concept is to be applied as a two-step process which: 1) determines whether or not the proposed research project is needed and necessary for the purposes of wilderness, and 2) the techniques and type of equipment needed to ensure that impact to wilderness resources and values is minimized. In the determination of minimum requirement, park superintendents are instructed to give the disruption of wilderness character and resources significantly more weight than economic efficiency and staff convenience during the decision making process. While the parks are provided with considerable license in the use and development of minimum requirement decision tools, the process finally adopted must be recorded and accompanied by appropriate environmental compliance documentation. Examples of minimum requirement decision tools are provided in the appendices of *Reference Manual 41# Wilderness Preservation and Management*.

Director's Order #41, accompanying the revised NPS policy statements for wilderness preservation and management, provides further guidance for applying the policy requirements concerning research in park wilderness. Section 8 (Scientific Activities) encourages the use of park wilderness for scientific purposes, provided that the benefits of research projects outweigh the negative impacts on wilderness values and the work is conducted "in accord with wilderness stewardship and preservation principles."

Conclusions

The increasing number of requests to conduct research in National Park Service wilderness, and the capacity of these activities to adversely impact wilderness values, have necessitated the need to establish agency guidelines which: 1) promote the use of established wilderness for legitimate scientific activities, and 2) preserves wilderness values through the application of minimum requirement protocols in assessing individual research projects. Guidelines for conducting research activities in wilderness have been issued in NPS *Reference Manual #41: Wilderness Preservation and Management*.

References

USDI. 1999 Chapter 6: Wilderness Preservation and Management. National Park Service *Management Policies*.

USDI. 1999 National Park Service *Reference Manual #41: Wilderness Preservation and Management* (including *Director's Order #41: Wilderness Preservation and Manag*ement).

The Aldo Leopold Wilderness Research Institute: A National Wilderness Research Program in Support of Wilderness Management

Vita Wright

Abstract—The Aldo Leopold Wilderness Research Institute strives to provide scientific leadership in developing and applying the knowledge necessary to sustain wilderness ecosystems and values. Since its 1993 dedication, researchers at this federal, interagency Institute have collaborated with researchers and managers from other federal, academic and private institutions to support and conduct research on high priority topics related to recreation, natural disturbances and nonnative species. This paper gives an overview of the research conducted through the Leopold Institute and suggests future wilderness research directions for these issues. Leopold Institute staff strive to make research applicable to management through all phases of the research process.

Expanding recreation use and development pressures outside wilderness make it increasingly difficult for managers to preserve natural conditions and quality wilderness experiences. To protect and restore wilderness ecosystems and experiences, wilderness managers must understand wilderness resources, and the threats to those resources. Rigorous scientific research can help managers understand these, including: 1) wilderness ecosystems, 2) biological and social impacts of human activities to wilderness, 3) the role of wilderness in larger ecological and social systems and 4) potential consequences of alternative policy and management decisions.

The Aldo Leopold Wilderness Research Institute was established in 1993 as an interagency program to provide scientific leadership in developing the knowledge needed to protect and preserve wilderness, parks and other natural areas and to communicate and apply this knowledge to wilderness management. Located on the University of Montana campus in Missoula, the Leopold Institute is an outgrowth of the U.S. Forest Service's Wilderness Management Research Work Unit of the Intermountain Research Station (now the Rocky Mountain Research Station), which was created in 1967. The Leopold Institute operates under an interagency agreement among the four U.S. wilderness management agencies—Forest Service (USDA), National Park Service (USDI), Bureau of Land Management (USDI), Fish and Wildlife Service (USDI)—and the U.S. Geological Survey (USDI).

The Leopold Institute's scientific staff include five full-time research scientists (social scientist, recreation ecologist, landscape ecologist, plant ecologist and zoologist), a biologist, data analyst and research application specialist. Research activities include in-house studies, as well as cooperative projects with researchers and managers from other agencies and universities across the United States. In addition to collaborative research, cooperative activities include exchange programs, support of visiting researchers, leadership in professional activities and societies and sponsorship of lectures, workshops and symposia.

This paper gives an overview of the types of research conducted through the Leopold Institute. It describes issues identified by Leopold Institute scientists and their collaborators as some of today's wilderness research priorities, illustrates these issues with examples of Leopold Institute-sponsored research and research application activities and suggests future wilderness research direction within the context of the established research priorities.

Priority Research Issues

Leopold Institute scientists conduct and support a variety of research projects to improve the understanding and preservation of wilderness ecosystems, and the associated human experiences and values. These include both ecological studies on how to define and maintain natural ecosystems and social studies on various aspects of wilderness experiences.

The Leopold Institute conducted a comprehensive issue identification and prioritization process during 1995-96 to identify core issues that would form the focus of the Institute's research efforts, and provide a wilderness research agenda within which scientists interested in these topics could work. Potential research topics were placed into three priority classes, or tiers.

The resulting tier-one priority issues were: 1) understanding natural disturbance regimes and the effects of their alteration by human actions, and developing strategies to manage and restore natural disturbances in wilderness ecosystems, 2) understanding the effects of recreation use and recreation management strategies on wilderness attributes and visitor experiences, and 3) understanding the effects of nonnative species and their management on wilderness. The majority of the Leopold Institute's past and current efforts and resources have addressed the first two

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issues. For each of these two issues, Institute scientists employed a systematic scoping process, gathering input from a wide cross-section of federal agency managers and scientists, university scientists and nongovernmental organizations, to identify important future research topics. The Leopold Institute has also supported initial investigations into the third issue.

Natural Disturbance Regimes, Impacts, and Ecosystem Restoration

Scientists at the Leopold Institute are currently investigating the critical issues of how to define and monitor natural conditions, how to restore fire disturbance regimes to wilderness ecosystems, and the causes of worldwide amphibian declines.

Defining and Monitoring Natural Conditions—The Wilderness Act mandates that each wilderness area be "protected and managed so as to preserve its natural conditions...affected primarily by the forces of nature." Natural areas such as wilderness are valued by society for reasons including the provision of recreational opportunities, educational and philosophical values, protection of biodiversity and the economic benefits to areas near wilderness. However, before managers can preserve natural conditions, they must understand what is natural. Reviewing the complex issues that go into defining naturalness, Landres and others (1998) offered a working definition of naturalness, addressed ecological variability in nature and presented a strategy for setting management goals related to maintaining naturalness. Landres and others (1999) further reviewed the potential applications and limitations of using the concepts of natural variability to define ecologically appropriate management goals.

In addition to defining natural, managers strive to understand whether wilderness areas are diverging from natural conditions. Cole and Landres (1996) reviewed significant threats to wilderness ecosystems and identified critical research needs for these threats. Cole (1994) demonstrated how a wilderness threats matrix can be used to link specific threats to wilderness attributes. Managers can use such a matrix to assess the impacts of specific threats, assess the potential effects of alternative management decisions, develop indicators and standards and identify monitoring needs.

Because ecological monitoring is an important component of protecting and preserving wilderness character, Landres (1995) developed a conceptual model to help determine the goals of ecological monitoring programs. Once the goals of local, regional or national level monitoring programs are determined, managers can use lists of variables such as those developed by Landres and others at a recent workshop on monitoring terrestrial vegetation, wildlife and aquatic systems.

When identifying threats and/or monitoring wilderness attributes, if managers determine the naturalness of a wilderness area is in jeopardy, they are faced with the dilemma of whether to manipulate the area to restore natural conditions or to leave the area untrammeled, and thus unnatural. This dilemma results from conflicting mandates of the Wilderness Act to maintain both natural and untrammeled conditions. Cole (1996a) described several options for solving this dilemma, including a compromise solution that would allow managers to manipulate some portions of wilderness areas to move these areas closer to the current understanding of natural conditions, while retaining other, untrammeled areas as reference examples of wilderness without direct anthropogenic manipulation. The former option allows managers to protect and restore areas impacted by disturbances, such as introduced plants and fire suppression, that threaten naturalness while the latter recognizes the need for humility and the fact that manipulative restoration efforts may produce unanticipated, irreversible and undesirable changes. Cole and Hammitt (in press) identify the dilemma of whether to manage for naturalness or wildness as fundamental for wilderness managers, and address the need for additional research to help address this complex issue. Landres (in press) also explored questions of risk and uncertainty in managing for a natural or wild wilderness and concluded that "doing the right thing" is often, in the end, based on a philosophical choice.

Fire Restoration—Fire suppression during the 20th century has altered vegetative structure and increased hazardous fuel accumulations in many wilderness areas. This has led to recognition of the need to restore and maintain fire as a natural process in fire-dependent wilderness ecosystems. The potential consequences of not maintaining fire as a natural process include increased fuel accumulations, increased probability of extreme wildfire occurrence in and near wilderness, and altered ecosystem structure and function. Parsons (1991) cautioned that attempts to restore natural fire in wilderness must assure that fires burning under unnatural fuel conditions come as close as possible to approximating natural fire effects.

Leopold Institute scientists have recently reviewed efforts and constraints to restoring fire to wilderness. For example, Parsons and Botti (1996) noted the disparity between the acreage burned (mean of 173 acres/year) in a giant sequoia grove under current National Park Service management and the estimated historic acreage burned (mean 2,600 acres/year) for that grove. Reviewing the status of fire restoration across the wilderness system, Parsons and Landres (1998) reported that suppression continues to play a dominant role in fire policy for all four wilderness management agencies. Differences in agency program approaches and reporting methods make it extremely difficult to assess the status and progress of natural fire restoration across the agencies managing wilderness. Most recently, Parsons (in press, a) discussed the potential need for increased prescribed fire use in some wilderness areas.

When the Leopold Institute asked an interagency group of scientists and managers to prioritize disturbance issues for future research, respondents overwhelmingly emphasized the importance of understanding and mitigating the effects of fire suppression and changing fire regimes on wilderness. Wilderness fire research priorities identified included: 1) understanding the social, ecological and institutional factors that keep managers from restoring fire regimes, 2) improving methods of assessing fire risk (ecological and social) at wilderness boundaries, 3) developing strategies to

reduce fire risk, 4) understanding short- and long-term effects of alternative management strategies, and 5) improving strategies for communicating with the public about fire and the consequences of management choices.

Amphibian Decline—Toads, frogs and salamanders are disappearing from wilderness areas around the world, exhibiting a decline that has the potential to permanently alter wilderness ecosystems and wilderness experiences. There is no doubt that amphibian populations are declining, but in many cases, scientists still do not know why. It is unclear how much of the decline is a result of human actions and how much is a result of naturally changing global conditions. Steve Corn, a scientist working for the Biological Resources Division of the U.S. Geological Survey and stationed at the Leopold Institute, is an active member of the World Conservation Union's Declining Amphibian Populations Task Force. This task force works to determine the nature, extent and causes of amphibian declines throughout the world and to promote ways to halt or reverse these declines. Specifically, Corn works to understand the factors that contribute to amphibian distribution and status, the effects of global changes on breeding amphibians and to develop monitoring and conservation techniques.

Global changes, such as a warming climate and atmospheric ozone depletion, have the potential to alter future distributions of vegetation and wildlife that occur in wilderness. For example, increases in life-damaging UV-B radiation at the earth's surface, as a result of the depletion of the earth's ozone layer, has been suggested as a potential cause of worldwide amphibian declines. In a literature review of potential causes for declines, including climate change, habitat destruction, introduced predators, and UV-B radiation, Corn (in press) cited studies with contradictory results on the potential contribution of UV-B radiation. Although Corn (1998) himself found no relationship between UV-B exposure and boreal toad embryo mortality, he continues to investigate the relationship between UV-B radiation and amphibians in Glacier National Park. Other recent research includes documenting amphibian distributions and declines in Rocky Mountain National Park (Corn and others 1997) and reviewing knowledge about amphibian distributions and causes for decline across the western United States (Corn 1994).

Recreation Values, Impacts, and Management

Leopold Institute scientists have a long history of addressing wilderness recreation issues. Current research topics, which were prioritized during the recent scoping process, include understanding wilderness visitor experiences, identifying the ecological impacts of recreation and impacted site restoration, evaluating low-impact education message content and communication media and developing and evaluating other recreation management tools.

Definition of Wilderness Visitor Experiences—The Wilderness Act defines wilderness as having "outstanding opportunities for solitude or a primitive and unconfined type of recreation." The lack of commonly accepted definitions for terms such as solitude, primitive and unconfined recreation has complicated the development of social standards and consistent management strategies for wilderness. In addition, as recreation use has increased (Cole 1996b, Cole 1996c), managers have noted an increasing expression of conflict among different wilderness user groups (such as stock users, hikers, commercial outfitters, long-term area residents). Thus, there is a need to better understand the range of desirable wilderness experiences that managers are trying to protect. Leopold Institute staff have conducted and supported research on visitor use by 1) developing methods to quantify use levels, 2) defining wilderness values and 3) investigating influences on wilderness visitor experiences.

Traditionally, managers have measured use and encounter levels as a way to assess whether opportunities for solitude are being maintained (Cole 1997a). Watson and others (in press) recently summarized techniques for estimating use levels that will help managers determine which use estimation technique to use. Watson and others (1998a) also reviewed methods to estimate intergroup encounter rates and offered direction on when to use which methods. In addition to monitoring use levels and encounter levels, managers need to understand how numbers of people encountered relate to experiences achieved during and after wilderness visits. Borrie and Roggenbuck (1998) found that different factors influenced visitor experiences during high-use and low-use periods.

Wilderness managers and users often focus on issues of solitude. Based on the results of a study of Grand Canyon visitors, Stewart and Cole (1997) found that solitude means different things to different wilderness visitors and can be experienced in settings with different levels of remoteness. Researchers have helped managers understand that other psychological, social, spiritual and inspirational factors, in addition to solitude, motivate people to visit wilderness (Dawson and others 1998). Thus, managers can more effectively address visitor needs by understanding the array of physical and social influences on wilderness trip expectations and trip evaluations. Watson and others (1992) lumped potential indicators of trip quality into five categories: site impacts, seeing wild animals, sound and sight intrusions, horse encounters and people encounters. Watson and Roggenbuck (1998) recently added challenge, primitive route finding and the opportunity to experience feelings of timelessness as important components of wilderness experiences.

With the increasing expression of conflict among wilderness user groups, managers must also understand the impacts of conflicting values among users on the quality of wilderness experiences. Recent research on user conflict supported by the Leopold Institute have found that 1) most visitors reported livestock detracted from their wilderness experiences (Johnson and others 1997), 2) horse users and llama users often had different opinions (Watson and others 1998b) and 3) different types of river floaters reported different experiences and attitudes (Watson and others 1998c). In the latter study, private floaters found more enjoyment in challenge, primitive skills, camping and cooking, while commercial floaters found more enjoyment in escaping from civilization, learning about people and

local history, and being with people. Watson's (in press) recent synthesis of knowledge on wilderness visitors and their visits included a discussion of trends in use and user characteristics, as well as how and why values and attitudes have changed. One long-term comparison of visitors to Oregon's Eagle Cap Wilderness found that visitors in the 1990s tend to be better educated, belong to conservation organizations and be more supportive of actions to maintain wilderness character than visitors were in the 1960s.

In addition to the topics mentioned above, research needs identified during the recreation scoping process include 1) understanding human relationships with the natural world, including the contribution of wilderness experiences to larger life issues, 2) developing strategies to incorporate different user values into management direction, 3) understanding the impact of management actions, such as use limits or use fees, on the wilderness user experience, 4) understanding user support for management alternatives and 5) developing and evaluating innovative methods to help managers identify important influences to visitor experiences.

Ecological Impacts of Recreation—Recreation use has the potential to cause substantial impacts to areas that are used repeatedly, such as campsites and trails, as well as portions of wilderness that are used less frequently. Research that helps managers protect natural conditions and quality wilderness experiences by understanding and minimizing these impacts includes identifying the biophysical impacts of recreation use to resources such as to water, soil, vegetation and animals, at various spatial scales, and identifying which factors influence the magnitude of these impacts. Leopold Institute researchers have a long history of studying the site-specific ecological impacts of recreation on vegetation and soil. Cole and others (1987) summarized the nature of ecological problems resulting from recreation use, including tactics for dealing with common wilderness recreation problems.

The Leopold Institute has recently contributed to several synopses related to the ecological impacts of recreation to soil, vegetation, animals, and water. Hammitt and Cole (1997) provided an in-depth look at these topics when they revised their textbook, *Wildland Recreation: Ecology and Management*, to offer detailed descriptions of problems that arise in wildland areas as a result of recreation use, as well as factors affecting these impacts and methods to manage these problems. Because campground impacts are pervasive and often receive management emphasis, McEwen and Cole (1997) reviewed types of impacts, factors influencing these impacts, patterns of impact development, strategies to minimize impacts and impact monitoring approaches. Cole's (1989a) source book describing techniques to monitor backcountry campsite impacts continues to be a valuable tool for wilderness managers.

Recent research has shown that factors influencing the magnitude of recreation impacts to campsite and trail vegetation include trampling intensity (Cole 1995a), resistance and resilience of different vegetation types (Cole 1995b), use intensity and duration by campers (Marion and Cole 1996) and packstock (Olson-Rutz and others 1996) and use type (Cole and Spildie 1998, DeLuca and others 1998). Other recent studies include a summary of the effects of recreation on wildlife (Knight and Gutzwiller 1995) and recreation impacts to songbirds (Riffell and others 1996). Additional studies on the topic of ecological impacts of recreation can be found by searching the Leopold Institute's publication list, obtainable from the Institute directly or through the Institute's web page (www.wilderness.net/leopold).

Future research priorities identified during the scoping process include studying the impacts of recreation to belowground soil systems, wildlife and aquatic systems, as well as the significance of recreation impacts over broad spatial scales. Research priorities related to the restoration of impacted sites include, 1) identifying factors that limit natural recovery on damaged sites such as trails, campsites and old roads, in different ecoregions and in different vegetation zones, 2) population biology, demography and reproductive ecology of plants used in restoration efforts, 3) effectiveness of existing restoration techniques to soil conditions, biotic diversity and vegetative cover and 4) how to improve restoration techniques, such as the addition of fertilizer, soil amendments, mulching, plant propagation and mycorrhizal inoculation used to accelerate restoration.

Low-Impact Education—Education is a tool commonly used by managers to promote low-impact behaviors in wilderness. This topic is a priority for wilderness researchers due to the facts that 1) extensive resources are already devoted to low-impact education, 2) many experts consider education as key to solving recreation problems and 3) little is known about the effectiveness of existing education programs.

Cole (1989b) described a variety of practices that managers can use to educate visitors to reduce impacts. These practices and existing educational programs such as Leave No Trace, which work to increase public awareness of practices they can use to minimize resource damage, require constant reevaluation of whether they are teaching the most appropriate messages based on current scientific understanding. Hampton and Cole (1995) revised the book *Soft Paths* to incorporate Leave No Trace messages and current research on minimum-impact techniques. Hendricks and Watson's (1999) recent investigation showed that the Impact Monster, a wilderness education skit designed in the late 1970s to teach minimum impacts techniques to children, is still widely used for third through sixth grade students. Suggestions for improving this program included avoiding stereotypes, being sensitive to cultural differences and emphasizing positive behavior.

Research priorities for education include developing the content of educational messages, as well as the success of media used to communicate these messages. In a recent study, Cole (1998) found that posting a banner reading, "Please take time to read these messages" at educational trailhead bulletin boards almost doubled the time that visitors allocated to reading posted messages. However, once hikers stopped to read the bulletin boards, their ability to retain the content of individual messages decreased with an increasing number of posted messages (Cole and others 1997a).

The scoping process on recreation concluded that additional understanding is needed on 1) which low-impact practices are most effective, 2) the factors that limit visitor compliance with low-impact recommendations and 3) the effectiveness of alternative messages and media methods.

Other Recreation Management Tools—Managers trying to protect wilderness visitor experiences, and minimize biophysical impacts of recreation, often consider imposing use restrictions. Leopold Institute researchers have contributed to the development and comparison of tools to help managers decide whether and when to initiate use restrictions and to determine whether these restrictions are accomplishing desired goals (Parsons 1986, Stankey and others 1985). Stankey and others (1985) developed the Limits of Acceptable Change (LAC) process in an attempt to address the conflict between recreation use and the resulting degradation of natural resource conditions and visitor experiences. In the decade since its development, wilderness managers have implemented the LAC process in a variety of situations. To reevaluate and increase the utility of the LAC and other similar planning processes, the Leopold Institute co-organized and published the results of a workshop on this topic (McCool and Cole 1997).

Other Leopold Institute investigations of use and resource allocation include 1) Cole's (1997b) questioning of whether low-use areas are currently receiving adequate protection from degradation, 2) Cole's (1995c) discussion of the problems related to use limits, 3) Watson and Niccolucci's (1995) investigation of the reasons behind visitor support of use restrictions and 4) Cable and Watson's (1998) comparison of alternative approaches for determining recreation use allocation for a large wilderness complex. Addressing management issues specific to high-use wilderness destinations, Cole and others (1997b) provided information on social and biophysical impacts, visitor responses and management options for such areas. They found that visitors to high-use areas were highly supportive of heavily impacted site closures and revegetation programs and were not bothered by the high encounter levels they experienced.

Leopold Institute staff conduct research to help managers assess other management tools. For example, Congress authorized a three-year Recreation Fee Demonstration Program in 1996 to examine the feasibility of generating funds from users for the operation, maintenance and improvement of public recreation areas, including wilderness areas. Under this program, federal land managers around the country have initiated fee projects such as permit reservations and fees for the use of campsites, trails and vehicle parking. Alan Watson has coordinated a variety of studies to help managers understand visitor responses to user fees. A number of papers on this topic have been published in theme issues of the *Journal of Leisure Research* (1999) and the *Journal of Park and Recreation Administration* (1999).

Nonnative Species

Although the issue of nonnative species has not yet been developed into a full research agenda, the Leopold Institute has supported recent investigations into the distribution and management of nonnative plants and the effects of nonnative fish stocking in wilderness.

Plants—In spite of legal mandates to maintain natural conditions, many wilderness areas have been impacted by the introduction of nonnative plant species. Some of these have the potential to drastically alter native ecosystem structure and function. In an effort to understand exotic plant issues related to wilderness, the Leopold Institute supported a survey of wilderness managers about the extent and control of nonnative plant invasions in the National Wilderness Preservation System (Marler, in press). Responses from wilderness areas across the country were used to develop a database of nonnative plant presence and management control efforts in wilderness. Current Institute-supported research projects attempt to understand how weeds spread into wilderness, the conditions that favor or discourage weed growth and reproduction and the influx of weeds after prescribed burning.

Fish—Over the past century, sport fish have been introduced into most of the naturally fishless lakes in U.S. wilderness areas. Fish introductions have changed entire lake ecosystems and communities, often with detrimental impacts to native fish and amphibians. Wilderness managers must make difficult and controversial decisions about how to balance the recreational opportunity created by historic nonnative fish stocking with the preservation of native fauna and flora in wilderness lakes. The Leopold Institute currently supports several ongoing studies related to this issue, including studies on the impacts of exotic trout to amphibians in wildernesses lakes in Idaho, California and Montana, and a study of exotic trout impacts to native invertebrates in Utah. The Leopold Institute co-organized a workshop, entitled "Effects of Fisheries Management on the Amphibians and Other Biota of Wilderness Lakes," to provide managers with the latest research results on this topic and to facilitate discussion among managers, scientists and wilderness users (Corn, in press). The results of this workshop are in preparation for publication as a compilation of research results and management recommendations.

Additional Research Issues

As a result of the 1995-96 issue prioritization process, tier-two issues were also identified. Although tier-two priority issues haven't been developed into full research programs, the Leopold Institute opportunistically supports research that addresses these issues. Tier-two issues include, 1) understanding the effects of livestock and livestock management on wilderness ecosystems, 2) understanding the relationships between wilderness and larger ecological systems and 3) understanding the role of wilderness in larger social systems. For example, recent Leopold Institute research on the value of wilderness within broader social systems includes 1) a study that found a seven-day wilderness experience program empowered and strengthened the skills and motivation of participating youth-at-risk, and reduced early terminations from the Federal Job Corps (Russell and others 1998) and 2) an investigation of wilderness values in the urban area of Los Angeles, California where ethnically and economically diverse survey respondents showed significant support for wilderness (Parker and Koesler 1998). Managing wilderness within broader ecological and social systems necessitates recognizing and overcoming the impacts of administrative boundaries and adjacent lands on wilderness management (Knight and Landres 1998).

The Leopold Institute also addresses broad issues related to science and wilderness, such as clarifying the role

of science in defining wilderness management objectives (Parsons 1998a), and addressing the appropriateness and conduct of scientific and management activities within wilderness (Parsons 1998b, Parsons, in press, b).

Research Application to Management

Part of the Leopold Institute's mission is to make research results directly useful and readily available to managers, educators, policymakers, user groups, and other scientists. In addition to publishing research results, Institute research is disseminated through the research application program. Examples of current research application activities include: 1) developing information sources such as databases, bibliographies, and libraries containing research relevant to wilderness management, 2) summarizing research findings and management implications for managers (Wright 1998a, Wright 1998b), 3) developing and implementing protocols to help managers make decisions, 4) conducting and participating in workshops, site visits and training sessions, and 5) developing partnerships between scientists and the users of knowledge gained through wilderness research.

Internet Web Site

The Leopold Institute web site (www.wilderness.net/leopold) includes introductory and background information on the Leopold Institute and its staff, research activities, a current publication list, and conference announcements. Over the past year, this web page has become the Leopold Institute's primary means of distributing the publication list, as well as the databases developed through the Institute. The web site is being expanded to provide additional scientific information on a variety of wilderness issues.

Databases

Leopold Institute staff recently updated and revised a database of the National Wilderness Preservation System, which was initially developed by the Bureau of Land Management. This database includes each wilderness area's correct legal name, establishing public law, date established, modifying laws, current acreage and administering unit(s), and state(s) where it is located. The database is currently accessible in a hard-copy publication (Landres and Meyer 1998) and the Leopold Institute's web site. Meyer and Landres are also developing a database of the legislative history on a variety of wilderness issues; that database will also be available through the Internet.

Conferences

The Leopold Institute staff organize conferences, symposia, workshops and technical sessions to summarize state-of-knowledge research on wilderness issues and provide opportunities for managers to interact with scientists over these issues. Recent workshop topics include the Limits-of-Acceptable Change process (McCool and Cole 1997), nonnative fish stocking in wilderness lakes and the uses (Corn, in press) and limitations of historical variability concepts for managing ecosystems (Parsons and others 1999). The Leopold Institute cosponsored and co-organized the 1999 Wilderness Science Conference published in this proceedings (Cole and McCool, in press), as well as the science program for the Sixth World Wilderness Congress in India (Watson and others 1998d, Watson and others 1999).

Site Visits

Leopold Institute researchers conduct site visits to assist natural area mangers with issues of national relevance. This includes working with Forest Service managers to develop a national strategy for wilderness recreation management that will prevent the degradation of near-pristine low-use areas, while maintaining high-use wilderness areas within acceptable levels of resource impacts. Other examples of site visits include consulting with BLM managers at the new Grand Staircase-Escalante National Monument to help refine monitoring protocols, consulting with managers on how to monitor fee impacts and how to initiate collaborative processes for reintroducing fire into wilderness, and meeting with managers from state and federal agencies to discuss the conflicts around enhancing wildlife habitat within wilderness. Additional recent site visits have been made to assess the need and options for restoring fire to mixed severity fire regime forests (Arno and others, in press) and to identify potential studies in wilderness areas containing extensive tree blowdown.

Conclusion

The Aldo Leopold Wilderness Research Institute provides a focal point for the development and application of scientific information necessary to understand and manage wilderness ecosystems. Specifically, the Leopold Institute provides a national center for scientists from different disciplines and backgrounds to address the wilderness research needs of land management agencies and organizations. Leopold Institute staff have worked with other wilderness experts to identify high priority research issues and specific research agendas related to recreation management and ecological disturbances. Past research has included topics related to recreation impacts, visitor experiences, and fire, vegetation and wildlife ecology. Results of some Institute research projects are applied directly to local management dilemmas, while others provide the theoretical background to answer broader wilderness management questions. Leopold Institute staff are dedicated to providing the quality, peer-reviewed research and application necessary to develop policy guidelines and management practices that assure sustainable wild ecosystems and their benefits and values endure for generations to come.

References

Arno, Stephen F.; Parsons, David J.; Keane, Robert E. In Press. Mixed-severity fire regimes in the Northern Rocky Mountains: Consequences of fire exclusion and options for the future. In:

Cole, David N.; McCool, Stephen F. Proceedings: Wilderness Science in a Time of Change. Proc. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Borrie, William T.; Roggenbuck, Joseph W. 1998. Describing the wilderness experience at Juniper Prairie Wilderness using experience sampling methods. In: Kulhavy, David L.; Legg, Michael H., eds. 1998. Wilderness & natural areas in eastern North America: research, management and planning; 1996 May 19-23; Gatlinburg, TN. Nacogdoches, TX: Arthur Temple College of Forestry, Stephen F. Austin State University: 165-172.

Cable, Suzanne; Watson, Alan E. 1998. Recreation use allocation: alternative approaches for the Bob Marshall Wilderness Complex. Res. Note RMRS-RN-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 7 p.

Cole, David N. 1989a. Wilderness campsite monitoring methods: a sourcebook. General Technical Report INT-259. Ogden, UT: USDA For. Serv., Intermountain Research Station. 57 p.

Cole, David N. 1989b. Low-impact recreational practices for wilderness and backcountry. Gen. Tech. Rep. INT-265. Ogden, UT: USDA For. Serv., Intermountain Research Station. 131 p.

Cole, David N. 1994. The wilderness threats matrix: a framework for assessing impacts. Res. Pap. INT-475. Ogden, UT: USDA For. Serv., Intermountain Research Station. 14 p.

Cole, David N. 1995a. Experimental trampling of vegetation. I. Relationship between trampling intensity and vegetation response. Journal of Applied Ecology. 32: 203-214.

Cole, David N. 1995b. Experimental trampling of vegetation. II. Predictors of resistance and resilience. Journal of Applied Ecology. 32: 215-224.

Cole, David N. 1995c. Wilderness management principles: science, logical thinking or personal opinion? TRENDS/Wilderness Research. 32(1): 6-9.

Cole, David N. 1996a. Ecological manipulation in wilderness—an emerging management dilemma. In: International Journal of Wilderness. 2(1): 15-19.

Cole, David N. 1996b. Wilderness recreation use trends, 1965 through 1994. Res. Pap. INT-RP-488. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 10 p.

Cole, David N. 1996c. Wilderness Recreation in the United States—Trends in Use, Users, and Impacts. International Journal of Wilderness. 2(3): 14-18.

Cole, David N. 1997a. Solitude: Researchers Continue to Delve into the Solitude Component of Wilderness. Signpost for Northwest Trails. January: 33-34.

Cole, David N. 1997b. Recreation Management Priorities Are Misplaced: Allocate More Resources to Low-Use Wilderness. International Journal of Wilderness. 3(4): 4-8.

Cole, David N. 1998. Written appeals for attention to low-impact messages on wilderness trailside bulletin boards: experimental evaluations of effectiveness. Journal of Park and Recreation Administration. 16(1): 65-79.

Cole, David N.; Petersen, Margaret E.; Lucas, Robert C. 1987. Managing wilderness recreation use: common problems and potential solutions. Gen. Tech. Rep. INT-GTR-230. Ogden, UT: USDA For. Serv., Intermountain Research Station. 60 p.

Cole, David N.; Landres, Peter B. 1996. Threats to wilderness ecosystems: impacts and research needs. In: Ecological Applications. 6(1): 168-184.

Cole, David N.; Hammond, Timothy P.; McCool, Stephen F. 1997a. Information Quantity and Communication Effectiveness: Low-Impact Messages on Wilderness Trailside Bulletin Boards. Leisure Sciences. 19: 59-72.

Cole, David N.; Watson, Alan E.; Hall, Troy E.; Spildie, David R. 1997b. High-Use Destinations in Wilderness: Social and Biophysical Impacts, Visitor Responses, and Management Options. Gen. Tech Rep. INT-RP-496. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 29 p.

Cole, D. N.; Spildie, D. R. 1998. Hiker, horse and llama trampling effects on native vegetation in Montana, USA. Journal of Environmental Management. 53: 61-71.

Cole, David N.; McCool, Stephen F. In Press. Proceedings: Wilderness Science in a Time of Change. Proc. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Cole, David N.; Hammitt, William E. In Press. Wilderness management dilemmas: fertile ground for wilderness management research. In: Cole, David N.; McCool, Stephen F. Proceedings: Wilderness Science in a Time of Change. Proc. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Corn, P.S. 1994. What we know and don't know about amphibian declines in the West. Pages 59-67 In: Covington, W. W.; DeBano, L. F., technical coordinators. Sustainable ecological systems: implementing an ecological approach to land management. Ft. Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. General Technical Report RM-GTR-247.

Corn, Paul Stephen. 1998. Effects of ultraviolet radiation on boreal toads in Colorado. Ecological Applications. 8(1): 18-26.

Corn, Paul Stephen. In Press. Fish stocking in protected areas: summary of a workshop. In: Cole, David N.; McCool, Stephen F. Proceedings: Wilderness Science in a Time of Change. Proc. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Corn, Paul Stephen. In Press. Amphibian declines: review of some current hypotheses. In: Sparling D.W., Bishop, C.A., Linder, G., eds. Ecotoxicology of amphibians and reptiles. Pensacola FL: Society of Environmental Toxicology and Chemistry.

Corn, Paul Stephen; Jennings, Michael L.; Muths, Erin. 1997. Survey and Assessment of Amphibian Populations in Rocky Mountain National Park. Northwestern Naturalist. 78: 34-55.

Dawson, Chad P.; Newman, Peter; Watson, Alan. 1998. Cognitive dimensions of recreational user experiences in wilderness: an exploratory study in Adirondack wilderness areas. In: Vogelson, Hans G., comp., ed. 1998. Proceedings of the 1997 northeastern recreation research symposium; 1997 April 6-9; Bolton Landing, NY. Gen. Tech. Rep. NE-241. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 287 p.

DeLuca, T. H.; Patterson, W. A., IV; Freimund, W. A.; Cole, D. N. 1998. Influence of llamas, horses, and hikers on soil erosion from established recreation trails in western Montana, USA. Environmental Management. 22(2): 255-262.

Doucette, Joseph E.; Cole, David N. 1993. Wilderness visitor education: information about alternative techniques. Gen. Tech. Rep. INT-295. Ogden, UT: USDA For. Serv., Intermountain Research Station. 37 p.

Gutzwiller, Kevin J.; Marcum, Heidi A.; Harvey, Henry B.; Roth, James D.; Anderson, Stanley H. 1998. Bird tolerance to human intrusion in Wyoming montane forests. The Condor. 100: 519-527.

Hammitt, William E.; Cole, David N. 1987. Wildland recreation: ecology and management. New York: John Wiley & Sons. 341 p.

Hampton, Bruce; Cole, David. 1995. Soft paths: how to enjoy the wilderness without harming it. Harrisburg, PA: Stackpole Books. 173 p.

Hendricks, William W.; Watson, Alan E. 1999. Wilderness educators' evaluation of the Impact Monster Program. Res. Pap. RMRS-RP-15. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 12 p.

Johnson, Laura C.; Wallace, George N.; Mitchell, John E. 1997. Visitor Perceptions of Livestock Grazing in Five U.S. Wilderness Areas—A Preliminary Assessment. International Journal of Wilderness. 3(2): 14-20.

Journal of Leisure Research. 1999. Volume 31, Number 3.

Journal of Park and Recreation Administration. 1999. Volume 17, Number 3.

Knight, Richard L.; Gutzwiller, Kevin J., eds. 1995. Wildlife and Recreationists—Coexistence Through Management and Research. Washington, DC: Island Press. 372 p.

Knight, Richard L.; Landres, Peter B., eds. 1998. Stewardship across boundaries. Covelo, CA: Island Press. 371 p.

Landres, Peter B. 1995. The role of ecological monitoring in managing wilderness. TRENDS/Wilderness Research. 32(1): 10-13.

Landres, Peter B. In Press. Protecting naturalness and wildness: a management dilemma and a social irony. In: Cole, David N.; McCool, Stephen F. Proceedings: Wilderness Science in a Time of Change. Proc. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Landres, Peter; Meyer, Shannon. 1998. National Wilderness Preservation System database: key attributes and trends, 1964 through 1998. Gen. Tech. Rep. RMRS-GTR-18. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 97 p.

Landres, Peter B.; White, Peter S.; Aplet, Greg; Zimmermann, Anne. 1998. Naturalness and natural variability: definitions, concepts, and strategies for wilderness management. In: Kulhavy, David L.; Legg, Michael H., eds. 1998. Wilderness & natural areas in eastern North America: research, management and planning; 1996 May 19-23; Gatlinburg, TN. Nacogdoches, TX: Center for Applied Studies, Stephen F. Austin State University: 41-50.

Landres, Peter B.; Morgan, Penelope; Swanson, Frederick J. 1999. Overview of the use of natural variability concepts in managing ecological systems. Ecological Applications. 9(4): (in press).

Marion, Jeffrey L.; Cole, David N. 1996. Spatial and temporal variation in soil and vegetation impacts on campsites. Ecological Applications. 6(2): 520-530.

Marler, Marilyn J. In Press. A survey of exotic plants in federal wilderness areas. In: Cole, David N.; McCool, Stephen F. Proceedings: Wilderness Science in a Time of Change. Proc. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

McCool, Stephen F.; Cole, David N., comps. 1997. Proceedings--Limits of acceptable change and related planning processes: progress and future directions; 1997 May 20-22; Missoula, MT (Lubrecht Experimental Forest). Gen. Tech. Rep. INT-GTR-371. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 84 p.

McEwen, Douglas; Cole, David N. 1997. Campsite Impact in Wilderness Areas. Parks and Recreation. February: 24-32.

Olson-Rutz, K. M.; Marlow, C. B.; Hansen, K.; Gagnon, L. C.; Rossi, R. J. 1996. Packhorse Grazing Behavior and Immediate Impact on a Timberline Meadow. Journal of Range Management. 49: 546-550.

Parker, Julia Dawn; Koesler, Rena. 1998. Urban populations as an impact on wilderness: a study of values in the Los Angeles Basin. In: Kulhavy, David L.; Legg, Michael H., eds. Wilderness & natural areas in eastern North America: research, management and planning. Nacogdoches, TX: Stephen F. Austin State University, Arthur Temple College of Forestry, Center for Applied Studies: 245-249.

Parsons, D.J. 1986. Campsite impact data as a basis for determining wilderness use capacities. In: Lucas, Robert D., compiler. Proceedings National Wilderness Research conference: current research; 1985 July 23-26; Fort Collins, CO. Gen. Tech. Rep. INT-212. Ogden, UT: USDA For. Serv., Intermountain Research Station: 449-455.

Parsons, D.J. 1991. Restoring fire to the Sierra Nevada mixed conifer forest: reconciling policy, science and practicality. In: Hughes, H.G.; Bonnicksen, T.M., eds. Proceedings, First Annual Meeting of the Society for Ecological Restoration. Madison, WI: Society for Ecological Restoration: 271-279.

Parsons, David J. 1998a. Integrating science into natural resource planning and management. In: Hill, Linda M., ed. 1998. Learning from the land: Grand Staircase-Escalante National Monument science symposium proceedings; 1997 November 4-5; Cedar City, UT. BLM/UT/GI-98-006+1220. [Publisher's location and name unknown]: 37-40.

Parsons, David J. 1998b. Scientific activities in wilderness-a workshop to address issues and concerns. International Journal of Wilderness. 4(1): 10-13.

Parsons, David J. In Press, a. The challenge of restoring natural fire to wilderness. In: Cole, David N.; McCool, Stephen F. Proceedings: Wilderness Science in a Time of Change. Proc. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Parsons, David J. In Press, b. The challenge of scientific activities in wilderness. In: Cole, David N.; McCool, Stephen F. Proceedings: Wilderness Science in a Time of Change. Proc. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Parsons, David J.; Botti, Stephen J. 1996. Restoration of fire in national parks. In: Hardy, Colin C.; Arno, Stephen F., eds. The use of fire in forest restoration. Gen. Tech. Rep. INT-GTR-341. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 29-31.

Parsons, David J.; Landres, Peter B. 1998. Restoring natural fire to wilderness: how are we doing? In: Pruden, Teresa L.; Brennan, Leonard A., eds. Proceedings: 20th Tall Timbers Fire Ecology Conference: Fire in ecosystem management: shifting the paradigm from suppression to prescription; 1996 May 7-10, Boise, ID. Lawrence, KS: Allen Press: 366-373.

Parsons, David J., Swetnam, Thomas W. and Christensen, Norman L. 1999. Uses and limitations of historical varibility concepts in managing ecosystems. Ecological Applications 9(4).

Patterson, Michael E.; Watson, Alan E.; Williams, Daniel R.; Roggenbuck, Joseph R. 1998. An hermeneutic approach to studying the nature of wilderness experiences. Journal of Leisure Research. 30(4): 423-452.

Riffell, Samuel; Gutzwiller, Kevin J.; Anderson, Stanley H. 1996. Does Repeated Human Intrusion Cause Cumulative Declines in Avian Richness and Abundance? Ecological Applications. 6(2): 492-505.

Russell, Keith; Hendee, John C.; Cooke, Steve. 1998. Social and economic benefits of a U.S. wilderness experience program for youth-at-risk in the Federal Job Corps. International Journal of Wilderness. 4)3): 32-38.

Stankey, George H.; Cole, David N.; Lucas, Robert C.; Petersen, Margaret E.; Frissell, Sidney S. 1985. The limits of acceptable change (LAC) system for wilderness planning. Gen. Tech. Rep. INT-176. Ogden, UT: USDA For. Serv., Intermountain Forest and Range Exper. Stn. 37 p.

Stewart, W; Cole, David. 1997. Truths About Solitude in Grand Canyon. In: Harmon, David, ed. Proceedings - Ninth Biennial George Wright Society Conference; 1997 March 17-21; Hancock, MI: The George Wright Society: 21-24.

Watson, Alan E. In Press. Wilderness use in the year 2000. In: Cole, David N.; McCool, Stephen F. Proceedings: Wilderness Science in a Time of Change. Proc. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Watson, Alan E.; Williams, Daniel R.; Roggenbuck, Joseph W.; Daigle, John J. 1992. Visitor characteristics and preferences for three national forest wildernesses in the South. Res. Pap. INT-455. Ogden, UT: USDA For. Serv., Intermountain Research Station. 27 p.

Watson, Alan E.; Niccolucci, Michael J. 1995. Conflicting goals of wilderness management: natural conditions vs. natural experiences. In: Chavez, Deborah J., tech. coord. Proceedings of the second symposium on social aspects and recreation research; 1994 February 23-25; San Diego, CA. Gen. Tech. Rep. PSW-GTR-156. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 11-15.

Watson, Alan E.; Hendee, John C.; Zaglauer, Hans P. 1996. Human values and codes of behavior: changes in Oregon's Eagle Cap Wilderness visitors and their attitudes. Natural Areas Journal. 16(2): 89-93.

Watson, Alan E.; Roggenbuck, Joseph W. 1998. Selecting human experience indicators for wilderness: different approaches provide different results. In: Kulhavy, David L.; Legg, Michael H., eds. Wilderness & natural areas in eastern North America: research, management and planning. Nacogdoches, TX: Stephen F. Austin State University, Arthur Temple College of Forestry, Center for Applied Studies: 264-269.

Watson, Alan E.; Cronn, Rich; Christensen, Neal A. 1998a. Monitoring inter-group encounters in wilderness. Res. Pap. RMRS-RP-14. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 20 p.

Watson, Alan E.; Christensen, Neal A.; Blahna, Dale J.; Archibald, Kari S. 1998b. Comparing manager and visitor perceptions of llama use in wilderness. Res. Pap. RMRS-RP-10. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 7 p.

Watson, Alan E.; Hunger, Don; Christensen, Neal; Spildie, Dave; Becker, Kurt; Comstock, Jeff. 1998c. Wilderness boaters: protecting unique opportunities in the Frank Church-River of No Return

Wilderness, Idaho, U.S.A. In: Watson, Alan E.; Aplet, Greg H.; Hendee, John C., comps. 1998. Personal, societal, and ecological values of wilderness: Sixth World Wilderness Congress proceedings on research, management, and allocation, volume I; 1997 October; Bangalore, India. Proc. RMRS-P-4. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 151-158.

Watson, Alan E.; Aplet, Greg H., Hendee, John C., comps. 1998d. Personal, societal, and ecological values of wilderness: Sixth World Wilderness Congress proceedings on research, management, and allocation, volume I; 1997 October; Bangalore, India. Proc. RMRS-P-4. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 158 p.

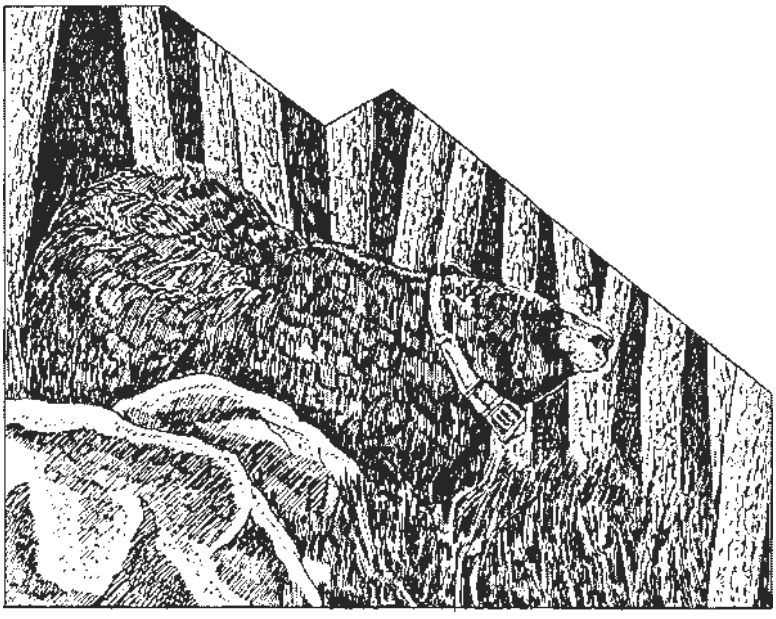
Watson, Alan E.; Aplet, Greg H.; Hendee, John C., comps. 2000. Personal, societal, and ecological values of wilderness: Sixth World Wilderness Congress proceedings on research, management, and allocation, volume II; 1998 October 24-29; Bangalore, India. Proc. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. (in press).

Watson, Alan E.; Cole, David N.; Turner, David L.; Reynolds, Penny S. In Press. Wilderness recreation use estimation: a handbook of methods and systems. Gen. Tech. Rep. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Wright, Vita. 1998a. News from the Aldo Leopold Wilderness Research Institute, Missoula, Montana, USA. International Journal of Wilderness. 4(2): 12.

Wright, Vita. 1998b. News from the Aldo Leopold Wilderness Research Institute: non-native fish stocking in wilderness. 5(1): 14.

6. Dialogue Session Summaries



Wilderness for Science: Pros and Cons of Using Wilderness Areas for Biological Research

Diana L. Six
Paul Alaback
Robert A. Winfree
Della Snyder
Anne Hagele

Abstract—Research is one of the intended purposes of wilderness. The Wilderness Act states that "wilderness may contain ecological, geological, or other features of scientific, educational, scenic, or historical value." This session specifically focuses on the pros and cons of conducting research in wilderness.

Research is one of the intended purposes of wilderness. The Wilderness Act states that "wilderness may contain ecological, geological, or other features of scientific, educational, scenic, or historical value." This session specifically focuses on the pros and cons of conducting research in wilderness. Therefore, I thought it might be helpful to present, at the beginning, the general criteria that must usually be met if a research project is to be conducted in wilderness. These criteria are:

1. The intended research activities are otherwise allowable under federal laws and regulations.
2. There are no alternatives to conducting the research in a wilderness area.
3. The project will not adversely affect physical or biological resources, ecosystem processes, or aesthetic values of an area or for a duration greater than necessary to meet research objectives.
4. The project will not interfere with recreational, scenic or conservation purposes of the wilderness over a broad area or long duration.

I think most of us agree that wilderness areas provide an invaluable resource for researchers in many of the sciences, not just the biological sciences. The benefits of working in wilderness are innumerable; for some studies, wilderness provides the only appropriate setting available. For instance, studies looking at natural processes are especially suited to wilderness settings. Indeed, studies looking at long-term natural processes would, in many cases, be impossible to conduct outside of the wilderness context.

For example, my research focuses on bark beetles. Bark beetles are little insects about 2-6 mm long, depending on the species. Some species kill trees, and they do this with such gusto and vigor that they are considered our most important forest pest. Bark beetles are usually present in the forest in very low numbers, often confined to single tree populations or small clusters of attacked trees widely scattered across the landscape. Under certain conditions, they can develop large outbreaks that kill thousands of trees. These outbreaks quite obviously can have great impacts on succession, fire patterns, wildlife and just about everything existing within the affected area and its immediate surroundings. However, besides being viewed as a pest because they compete with us for timber, increase fuel loading and affect aesthetics by killing trees, they are also an integral and necessary part of our forest ecosystems. They are a natural disturbance agent that our forests have coevolved with and a major force determining successional patterns and ecosystem dynamics.

A lot of research has been conducted over the decades on how to manage bark beetles to avoid timber losses. However, very little is known about their population dynamics and their role in ecosystem dynamics. Studies in managed areas are difficult. Silvicultural and pest management of stands greatly alter beetle population dynamics and disrupt long term field experiments and observations. To properly study bark beetle population dynamics, one must work in unmanaged areas of substantial size for relatively long periods of time. These requirements eliminate most, if not all, national forests, state, and private lands where beetles are usually managed as soon as populations begin to expand. Wilderness remains the only appropriate location for such studies. The point I would like to emphasize is that, in many cases, wilderness areas provide critical outdoor laboratories, and sometimes, the only laboratory.

On the other hand, while wilderness areas provide desirable and often optimal conditions for many studies, some studies are not at all appropriate. Given that wilderness is described in the Wilderness Act as an area untrammeled by humans, some studies are immediately and correctly excluded because of their highly disruptive or manipulative natures. However, for studies involving less disruptive experimentation or observation, working within the confines of legal and ethical restrictions can sometimes be

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difficult. Restrictions constraining research are often not clearly stated or evenly applied. This situation is not easily remedied because the constraining factors may not lend themselves to precise definition or consistent applicability, especially because research projects are likely to require evaluation on a case by case basis. In addition, many researchers often avoid working in wilderness because the permitting process can be intimidating and/or frustrating. The need is apparent for clear, consistent and understandable policies on research in wilderness.

The purpose behind organizing this dialogue session was to bring together researchers, managers and other interested parties to discuss the positive and negative aspects of doing research in wilderness areas. The session began with short presentations by panelists and concluded with open discussion on how benefits to researchers and to wilderness areas may be increased through appropriate research, as well as on how to alleviate some of the negative aspects of conducting wilderness research.

Panelists

Why Do Ecological Research in Wilderness?
Paul Alaback

The Scientific Opportunity—As ecology moves toward providing increasingly more useful information for improving natural resource policy and a more rigorous basis for management, it is increasingly impelled to tackle more complex and multidimensional questions. Since ecosystems are so complex and little understood, we cannot at this time, or any time in the foreseeable future, capture the full array of historic and contemporary ecological influences on ecosystems across a range of scales, in either the laboratory or a computer model. We need to have nature as our laboratory.

This complexity is our greatest challenge. Since the temperate forests I have studied are composed of species of great antiquity which have adapted to a broad range of climatic and natural disturbance-induced stress, mostly before the advent of humanity, it is key to understand how ecosystems work in a "natural" physical landscape and climatic regime. This is our essential scientific framework, which provides a critical context for most questions of human alteration of these patterns and functions.

While some wilderness areas suffer from varying degrees of global to regional-scale human impacts, they still hold more promise for studies hoping to unravel clear cause-effect ecological relationships than for studies that use ecosystems which have been variously affected by both known and unknown human influences. One particular category of ecological inquiry absolutely requires wilderness landscapes: landscape ecology. One of the key objectives of landscape ecology is to understand the influence of ecological factors that vary over a range of scales on ecological structures and processes. Wilderness areas are, by definition, the only places where such studies could be done without additional complications of human disruption of landscape structure and function.

I would like to also point out that some philosophers, historians and policy makers have tended to over generalize the extent of global human alteration of wilderness ecosystems and in so doing underestimating the value of wilderness as a scientific resource. The wilderness ecosystems that I have studied include some of the most pristine and least impacted by humans on Earth. For example Admiralty Island in Southeast Alaska is a wilderness area nearly 400,000 ha, which aside from a small portion of coastline on the north side, is a complete and intact ecosystem completely surrounded by a generous buffer of cold ocean. No significant alteration of disturbance regimes has occurred and all the key large and wide-ranging mammal and bird species that occurred 2,000 years or more ago, such as grizzly bears, and bald eagles continue to have healthy thriving populations.

In such unaltered wilderness areas scientists can understand clearly what factors affect ecological processes across a range of scales up to hundreds of thousands of hectares. Some wilderness reserves in Chile and Argentina also offer similar opportunities to ecological scientists. Many sites also occur in boreal, polar and even in some tropical ecosystems. Even when there has been some human-induced disturbance in these ecosystems the disturbance tends to be better defined and more conducive to study than in unprotected areas. An example would be old roads and clearcuts and the opportunity they afford for understanding long-term patterns of ecosystem recovery without complications of firewood cutting, salvage logging, human use of logging roads etc. which often compromise these studies in unprotected areas.

So what's the problem?—So why aren't these large pristine wilderness areas key centers of ecological research, as would be assumed given the above reasoning and the direction given in the Wilderness Act especially in the National Antiquities Act (affecting Admiralty Island, Escalante and Misty Fjords National Monuments in particular)? The examples cited above have had only a modest history of research use.

1. It is very expensive to conduct research in these remote regions. These coastal wildernesses are accessible only by boat or airplane, and weather frequently prevents safe travel over much of the year. None are close to major universities, so travel even to the general vicinity of these wilderness areas is expensive.
2. Wilderness areas generally do not represent either a broad range or a random sample of ecosystems within a region so they cannot be used as appropriate study sites for some studies without producing a biased or limited result. This is particularly true in interior mountainous regions, where wilderness generally represents only high-elevation sites; in coastal and high latitude areas, this may be less problematical.
3. Research that requires equipment or delicate electronics is very difficult because of the lack of control of climatic factors and generally nonexistent facilities for such research within wilderness.
4. It is difficult to travel efficiently within these large and rugged wilderness areas, leading to studies with small and not well distributed samples sites, compromising statistical rigor and inference.
5. Despite general legislative support and encouragement for research, there are often administrative barriers, varying from more involved permission procedures to restrictions in travel, use of equipment, establishment of

permanent plots, sampling restrictions and even location of campsites and timing of research activity.

6. There is often a lack of good communication and understanding between managers and scientists, leading to unnecessary amplification of the above problems.

For examples, some of my colleagues have been told they needed to establish campsites that were not visible to tour ships that traveled through study fjords, significantly compromising field efficiency. In some cases, plots could not be randomly located because of considerations of potential dispersed recreational use. Restrictions on tree or plot markers have made plot relocation difficult and reduced scientific precision for long-term studies. In some cases, environmental activists removed all plot markers from ecological studies in wilderness areas, leaving notes for the researchers in which they detailed their objections to how these markers compromised their wilderness experience.

Solutions—There many possible ways of mitigating problems associated with field ecological research in wilderness areas. As technology advances, some of these issues have become less important. For example, many landscape studies can effectively utilize remote sensing technologies, reducing requirements for extensive field plot sampling. Computer technologies also offer opportunities to reduce the visibility or even remove the necessity of having plot markers. These technologies may also reduce study costs by increasing field sampling efficiency.

If wilderness management agencies and nongovernment organizations (NGO's) that need more scientific information about wilderness areas developed more broadly based and well-funded grant programs, a larger base of scientists might be recruited to conduct wilderness studies. This program could aid communication between managers and scientists at the same time. For example, in British Columbia, NGO's successfully attracted a broad range of scientists internationally at minimal cost, simply by helping with logistical support and using existing scientific information networks to advertise the scientific values of their areas. In Alaska, a foundation is being organized to accomplish a similar goal for Admiralty Island. Key to these efforts is the establishment of a combined manager/scientists committee to set goals and determine evaluation criteria for proposed research projects.

Scientific use of wilderness areas is very different from recreational use. Wilderness managers sometimes focus their attention primarily on recreational issues in wilderness areas. Promotion of scientific use of wilderness may require some very different management philosophies. There is a need for careful evaluation of policies and procedures regulating scientific use of wilderness areas to see how management goals of resource protection and enhancement of visit or uses can be balanced against potential benefits or the need for scientific study of these unique areas. The dilemma is that these few protected areas in world, generally less than 6% of terrestrial ecosystems, are the best or even only places for both answering certain scientific questions and engaging in certain kinds of recreation and resource protection. Of course, determining the best ways to achieve all these management goals should itself benefit from more research in wilderness. So the resolution of these problems should be of potential benefit to all wilderness users and managers, not just scientists.

Designation and protection of additional areas, with regard to wilderness as a scientific resource, could also play a major role in promoting scientific utilization of wilderness. For example, when the French Pete additions to the Three Sisters Wilderness in Oregon were approved, the scientific value of this wilderness was enhanced vastly beyond the mere addition of land area. Now the wilderness includes productive low-elevation secondary forest and riparian ecosystems, in addition to the previously protected high-elevation forests, lakes and meadows that buffer this addition. Recent additions of protected land in the Tongass National Forest also have had generally greater scientific value than the original wilderness system in the area, including broad geographic representation of pristine old-growth riparian forests, for example, which are key to many local and even global questions of biodiversity conservation.

Management of wilderness landscapes, including the surrounding matrix, also has a key affect on the usefulness of wilderness as a resource for science. Resolution of boundary issues in highly fragmented wilderness areas, for example, will be of great benefit, both for resource protection and for the value of the wilderness as a scientific resource since it will greatly amplify the ecological integrity of smaller wilderness areas. In this case, the solution may not require the politically difficult and costly allocation of resources to land acquisition but could include promoting more compatible management of surrounding areas. For example, open-pit mining, ski areas or motorized and intensive recreation development on wilderness boundaries reduce the effective size of wilderness ecosystems. Selective logging or other intermediate levels of resource development activities could actually expand the effective wilderness for many ecological functions and processes.

There should be ample opportunities to enhance scientific understanding of wilderness without unduly compromising recreational opportunities and resource protection. Increased recognition and need for scientific information about wilderness, both for general understanding of ecology and to help improve management of wilderness, combined with better communication between managers and scientists, should help encourage more research in wilderness and also aid in its implementation in policy and management.

Wilderness Science Issues at Grand Canyon National Park

Robert A. Winfree, Della Snyder, and Anne Hagele

More than 90% of the Grand Canyon is managed as wilderness. Each year, the Park's research office handles about 150 permit applications for about 80 new or continuing studies. We start with the assumption that scientific inquiry is appropriate and beneficial for resource management. However, because of the high demand for access to this Park (five million visitors per year), and the need to manage for appropriate levels of use, permits are required for scientific studies, specimen collecting, camping, boating, caving and aircraft use.

We provide prospective researchers with a package of information fo r planning their work at Grand Canyon. The package explains the information needed for evaluating a proposal, identifies areas with special restrictions and out-lines standard permit conditions.

The first step in proposal review is to determine if all the required information has been provided. Frequently, proposals lack detail on the specific methods to be employed, the means of reaching the study site or the specific location of the study site. Consequently, permit office staff spend a fair amount of time fleshing out the details with applicants.

Once we have a complete proposal, we evaluate it for potential impacts to natural, cultural and recreational resources, including social values such as solitude and natural quiet. Eleven factors are considered in this part of the proposal evaluation, including: means of access, use of mechanized or motorized equipment, magnitude and duration of effects, frequency of disturbance, group size, safety, cost/benefit considerations, scheduling, significance and urgency of the study and location.

Each factor is represented by a column in the Wilderness Impact Matrix (table 1), and each column is divided into blocks. Blocks are arranged in descending order, with the most complex and controversial activities at the top of the table. The reviewer selects the block(s) in each column that best describe the proposal. The columns are further subdivided with a line. Studies involving activities "above the line" frequently have substantial issues that need to be resolved. We then work with the researcher to consider alternatives to lower the overall impact. An important point about this process is that all 11 factors are considered significant, and most of them are interrelated.

If potential impacts are identified, the evaluation shifts to considerations of alternatives through a minimum requirement analysis. The following questions are asked:

- Is the information really needed? We rely on peer review and resource management plans to determine the importance of the proposed work.
- Can the information be collected outside of the wilderness? This is feasible for some work along the wilderness perimeter and for research that is not site-dependent.
- Can the magnitude, duration and frequency of biophysical impacts be minimized, and can the social impacts be reduced?

- through alternative scheduling of activities when visitors are not present in the area,
- through erasing evidence of the activity by restoring the study site to its original appearance,
- through alternative equipment or research designs that use less intrusive methods to complete the objectives.

Finally, the proposed alternatives are re-examined to determine if they are likely to significantly compromise other important factors. Has safety or statistical confidence been reduced? Have costs or difficulty increased to a point where current work may not be completed, or where future work may not even be proposed?

Depending on the specific study objectives, a low-intensity approach may serve the purpose, or it may not work at all. However, consideration of alternatives, combined with the flexibility to select the most appropriate alternative enables information collection to proceed with minimal resource impact and minimal disturbance to visitors. We believe that it should not be necessary to compromise scientific inquiry or wilderness preservation, as long as scientists and resource managers are willing to work cooperatively toward common goals. The evaluation of research proposals, using the methods described above, are a process to accomplish these ends.

Dialogue Session Discussion

Discussion began with a comment that wilderness managers often tend to place the recreational values of wilderness above those of research. It was felt that research should also play an important role and that research has the potential to provide considerable benefits to wilderness areas. Several members of the audience felt that the benefits of research are not often considered by managers. These perceptions may, in part, stem from an approach by many managers to focus mostly, or completely, on the problems associated with the research, rather than the potential benefits. It was felt that focusing on research as a problem rather than as a positive factor that can benefit wilderness has led to a devaluation of science and an attitude that research in wilderness must be hidden, that the public should not be aware of its presence. It was suggested that the focus should shift from trying to hide science to showcasing it. As part of this showcasing, scientists conducting research in wilderness could develop interpretive literature or displays of their projects for visitor centers to describe how their project increased our knowledge of wilderness.

A related comment was that wilderness areas are some of our most biologically important areas, but also, those that we know the least about. By encouraging research, not discouraging it, we can learn more about wilderness, and in so doing, increase our understanding of its needs and management and aid in its protection.

Several members of the audience stated that increased communication between scientists and management would be a good way to tackle many problems associated with conducting research in wilderness. Early communication (pre-application rather than post-application) was seen as a way to increase management's understanding of the value of the research and to develop good working partnerships.

Other concerns voiced by audience members were: discrepancies among agencies and regions in how research applications are reviewed, lack of staffing to handle large numbers of applications and frequent changes in managerial staff, resulting in inconsistencies in the administration of projects.

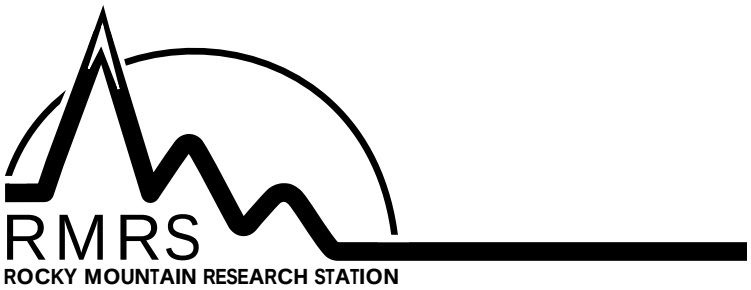
Table 1—Wilderness Impact Matrix. **Permit No:**

Means of Access[1]	Mechanized/Motor Equip.[2]	Magnitude of effects	Duration of Effects	Frequency of Disturbance	Field Crew	Safety	Cost/Benefit Factors	Scheduling	Significance & Urgency	Location
☐ Helicopter	☐ 2-cycle combustion engines (e.g., generators, pumps, saw drill)	☐ Potential regional or greater effect (e.g., species introduction).	☐ Permanent modification of park resources or adjacent areas (e.g., construction of a permanent study platform, field laboratory, or quarters; alteration of nonrenewable resources, excavation of archaeological or paleontological	☐ Continuous or near continuous activity (e.g., permanent field laboratory).	☐ Multiple group encampments or very large groups (e.g., 12 or more persons).	☐ High perceived risk to project personnel, visitors, or park staff from proposed activities. Training, safety gear, and other reasonable precautions do not appear sufficient to mitigate risk.	☐ Cost of NPS requirements associated with the proposed activities will make completion of the primary study objective infeasible.	☐ Timing of access is critical, and may be spur-of-the-moment. Essential data can only be collected within a short window of time. (e.g., studies of short term or unpredictable phenomena, floods, migrations, fire, seismic activity).	☐ Proposed activity is deemed inappropriate for NPS areas (permit will be denied).	☐ Activities proposed for restricted-access locations identified in the Superintendent's Compendium.
☐ Fixed wing aircraft	☐ 4-cycle combustion engines (e.g., generators, pumps)	☐ Potential effects extend over a broad area within or adjacent to the park unit (e.g., fire, river manipulation, extensive aircraft use).	☐ Long-term impacts (6 months to several years) to renewable resources (e.g., tree damage, population manipulation, excavation in recent sediments above mean high water).	☐ Frequent, long term activities (seasonal encampments).	☐ Large group encampment (e.g., 7-11 persons).	☐ Participation of essential personnel will not be possible under existing safety or logistical stipulations. Other qualified personnel are not available (i.e., can't complete primary study objective given	☐ Permit stipulations are expected to increase cost to the point that meeting the secondary objectives will not be achieved.	☐ Study has specific seasonality and site visits must be made during pre-established time frames (e.g., migratory wildlife, plant or animal reproduction, seasonal growth, seasonal visitation).	☐ Importance of study, or the need for conducting the study within an NPS area, is not supported by the proposal (permitting decision will be postponed pending major proposal revision).	☐ Activities under consideration are planned for portions of the park that are managed as Wilderness areas.
☐ Off-road motorized vehicle (e.g., truck, auto, ATV, snowmobile).	☐ Solar, battery, wind, current, and human powered mechanical devices.	☐ Potential effects confined to multiple small areas (e.g., multiple, small sampling plots and excavations).	☐ Seasonal impact (2-6 months, e.g., removal of seasonal plant growth, disturbance of beach deposits).	☐ Multiple overnight site visits.	☐ Small group encampment (2-6 individuals).	☐ Participation of preferred, but nonessential personnel may be limited by safety or logistical considerations, inaccessibility of site, or personal capabilities (e.g., technical rock climbing, hike out from river). Other qualified individuals can be available to complete task.	☐ Permit stipulations will increase costs to the point that other, equally important, studies will be negatively affected.	☐ Study objectives can be met at any time of year subject to convenient scheduling of personnel, equipment, access, funding, etc (i.e., work is not seasonal, resources re relatively stable, e.g., geologic strata, archaeology, paleontology, forest history).	☐ Significance of study and need for conducting activities in protected NPS areas is letters of recommendation from the investigator's institution and colleagues, but is not sup- ported by qualified independ-ent peer reviews (permitting decision may depend on a compelling justification by principal investigator or authority if there is any potential for resource impacts or interference with visitors).	☐ No activities planned in NPS wilderness areas.
☐ No mechanized devices.	☐ Probable effects confined to a single study site, which will be restored and is out of public view.		☐ Extended impact (obvious to casual observers for 2-4 weeks).	☐ Multiple daytime site visits (e.g., repetitive surveys, data collection).	☐ Single individual.	☐ Broad participation of study team may be possible, but will require development of additional skills, special training or certification, guide services, special supplies or equipment (e.g., backpack, river trip, winter camping).	☐ Permit stipulations have no lasting significant effect on ability to complete the study, or on institutional capabilities.	☐ Study objectives have a high probability of being met through opportunistic sampling (e.g., river guide monitoring of beach sites, participation on river trips on a space-available	☐ Significance of study and value to the park unit is clearly recognized by qualified independent peer reviews and by park management.	
☐ Sport or utility watercraft (i.e., frequent upriver travel) during motorized season (Dec 16-Sept 15).		☐ Probable effects will be hard to detect without prior knowledge (e.g., limited sampling of loose geologic materials, seasonal plant growth, water, or air).	☐ Short term impact (1 day to 2 weeks, e.g., surface water dye studies, overnight field excursion).	☐ Single overnight site visit.	☐ No additional personnel placed on site, activities concurrent with approved site visits for other studies.	☐ Participation of study team is not limited by safety, logistical considerations or permit stipulations.	☐ Proposed alternatives are expected to reduce total project costs.		☐ Broad recognition for the importance of the study exists at park, regional, and national/internation al level. Data are deemed important to Solving	
☐ Motorized, quiet watercraft (4-cycle engines required) launching during motorized season, Dec 16-Sept 15, principally downriver travel.		☐ No physical site impacts anticipated (e.g., photography, sound or climate monitoring).	☐ Instantaneous disturbance (e.g., seismic survey blast).	☐ Single daytime site visit.	☐ No site visit.				☐ Need for studies on this topic is documented in the park's current Resource Management Plan.	
☐ Non-motorized wheeled vehicles (e.g., bike, wagon) only above the canyon rim.			☐ No apparent impact.	☐ No site visit (e.g., high altitude remote sensing).						
☐ Oar powered watercraft (e.g., raft, dory, kayak).										
☐ Approved pack animals (e.g., mule, horse)										
☐ Human powered (e.g., day hike, backpack, ski, climb).										

[1]Use restrictions apply to all forms of access except day hikes and public roads.

[2]Use of quietest available technology is required.

NOTE:>>Each column of this table represents one set of ranking criteria (e.g., significance, safety, effects on park resources, etc.). Proposals that match descriptions at the top of the column are frequently complex and controversial. Activities above the dark line require evaluation of alternatives. Some may require lengthy impact assessments and negotiations prior to a permit decision. Decision making is simpler for proposals matching descriptions near the bottom of a column.



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